FINAL REPORT

SPACE SHUTTLE POWERED ELECTRICAL CONNECTOR DE-MATE TESTS

Prepared by

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Under P. O. T-2862T

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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DATE: October 15, 1994

SUBJECT: Final Report for Contract "Space Shuttle Powered Electrical Connector De-mate Tests - P. O. #T-2862T

I. INTRODUCTION

The test program being reported on here is designed to determine the effects of the charged plasma environment on the shuttle electrical system. Of particular interest is the effects of the plasma environment on powered electrical connectors as they are demated.

The present test program will concentrate on a single pin/socket pair with no connector shell or housing. No other pins or sockets will be configured with the test pair. Undamaged pin/socket pairs will be reused for other required tests; damaged pairs will not be reused. The criteria for damage were: any unusual output on the chart recorder, any unusual meltdown or metal deposition from a pin or socket, or any difficulty in mating the pin/socket pair.

The socket was always connected to the positive side of the power supply, while the pin was connected to the load as shown in Figure 1.

The pin/socket gage sizes used were: 8, 12, 16, 20, and 22. The currents applied were as shown in the table of Figure 2 and the voltage in all tests was 33 volts dc.

II. TEST DATA

22 AWG PIN/SOCKET

Applied currents were 1.5A, 3.7A, and 3.8 amps. Small arcs occurred in all three currents. These currents did not correspond to the listed currents in the test matrix because of an instrumentation problem discovered after the test. It is notable that even at these lower currents arcs occurred. The damage to the pin and socket was minimal and they were reused each time with no difficulty. After the 3.8 amp run, there appeared to be some carbon deposit in the socket but there was no difficulty remating the components.

Instead of re-running all the above tests at the required currents, we ran only the highest current, 10.6 amp. If damage to the components were to occur, we would then do the other currents at the required levels. Again, there was an arc, but minimal damage occurred.

20 AWG PIN/SOCKET

For the three currents 6.5, 13.0, and 16.3, there were slight arcs and the gold plating vaporized form the tip of the pin. No damage or effects of the arcs were observed in the sockets and all components could be remated and were reused.

16 AWG PIN/SOCKET

At 33V/9.3A, the arc resulted in the plating at the pin tip being vaporized and the outer edge of the socket was slightly burned; it appeared to be on the verge of melting at that spot. There was no problem remating the pair and they were reused.

At 33V, 18.5A, again there was an arc, and the tip of the pin experienced more loss of plating material. No pitting was observed on the tip. The socket was discolored, but there was no difficulty remating. The pair was reused.

At 33V/23.1A, more plating was vaporized from the pin tip and the edge of the socket melted down. The pin/socket pair probably could not be remated.

In all three of these tests the current output from the chart recorder showed a slight oscillation during the demate. The arc at 23.1 amp had a more noticeable effect on the current output on the chart recorder than the other currents.

12 AWG PIN/SOCKET

At 33V/14.8 amp, there was a bright arc which burned the socket and affected the current and voltage outputs. There was no problem remating the components and they were reused.

At 33V/29.5A, there was a bright arc. The pin lost some plating and there was a slight melt on the top edge of the socket. The damage was minimal and they were reused.

At 32V/36.9A, there again was a bright arc and the pin lost more of its plating. The components could be reused if necessary.

8 AWG PIN/SOCKET

At 33V/45A, there was a large arc, there was a loss of plating metal from the pin tip, and the tip of the socket melted in four places. The wire leading to the pin and socket was noticeably warm for the brief amount of time in which the components were powered. Power was on for

no more than three minutes. Since heat conduction occurs mainly by radiation, we thought there may be a problem with the rated current. We later tested 1/0 AWG pin/socket pairs for an extended period of time for a temperature study. This data appears in the last section of this report. During the demate there was a sustained arc at about 25 to 30 amps while the voltage across the load dropped to about 20 volts. The arc voltage then was in the range of ten volts at a power level of 300 watts. The pin and socket were not reused.

AT 32V/90A, there was also a sustained arc and the voltage across the load again was 15 to 20 volts. We did not have a current output for this run. The pin and the socket melted.

At 32V/60A, again there was a sustained arc which lasted until power was turned off. The arc voltage was 10 to 15 volts and the arc current was 40 amps initially, and then rose sharply to 120 amps. Again, the pin and socket melted; the socket was completely closed up by molten metal. One can see from the current output that there is an initial arc followed by a more intense arc. The same sequence could be observed by looking at the video of the test frame by frame.

III. ARC THRESHOLD FOR 8 AWG

Because of the sustained arc at 60 amps, we ran further tests to determine the threshold for sustained arcing of a 8 AWG pin/socket combination at 32 volts.

At 32 V/40A, again large amplitude spikes occurred on a sustained arc. Current fluctuations varied from 0 to 140 amps. Metal plating from the pin and socket covered the clamping apparatus. The outer shell of the socket melted in places.

At 32V/30A, there was a slight arc and there was no problem mating the pin and socket in vacuum.

At 32V/35A, there was a sustained arc and metal plating. A glow discharge was observed between the pin and socket.

At 32V/32.5A, there was also a sustained arc and glow discharge.

Based on the above data, the threshold is seen to be 30 amps.

IV. REPEAT TESTS

We also repeated some earlier tests to check on the reproducibility of data and to have a better video record.

At 32V/36.9, the 12 AWG pin and socket had a bright arc, as in its previous test. There was no hint of a sustained arc. The threshold for a sustained arc of the 12 AWG pin/socket pair is greater than 36.9 amps while that of the 8 AWG is about 30 amps. Both sockets had outer edges which were rolled over at the top to minimize an edge effect. The two gages may have differed in the type of metal plating utilized on the pin and socket. As the pin and socket began to demate, there is a rapid heating of the metal. If different plating metals were used, the one with the lower vaporization point would more readily vaporize to create a local atmosphere to be ionized. This particular point should be considered later.

At 32V/23.1A, the 16 AWG pin/socket pair had a bright arc but no damage, as in its previous test.

V. 1/0 AWG TESTING

Even though the 1/0 AWG pin/socket pairs were not included in the requirements for these tests, we decided to test their arcing threshold for high currents at 32V.

At 32V/50A, the 1/0 AWG pin/socket pair arced slightly. When re-mating the pair under vacuum, the tip of the socket glowed red due to resistance heating. It was mated and used again.

At 32V/60A, there was a bright arc but no damage.

At 32V/70A, again there was a slight arc but no damage

At 32V/80A, there was an arc and a glow discharge. The discharge probably would have been sustained if the pin and socket were separated at a slightly lower speed. We would term 32V/70A to be the threshold for sustained arcing in a 1/0 pin-socket pair.

At 32V/90A the arc lasted longer and at 32V/100A, it was obviously sustained.

VI. EFFECT OF DEMATE SPEED FOR 1/0 AWG PIN AND SOCKET

Because of the large degree of friction encountered in demating the 1/0 AWG pin and socket, we had to use a new high torque motor system. Early tests with this system did not give us reliable data on the demate speed because the motor could not demate at the high speeds we initially tried. Again, because of the large frictional forces, the system would automatically start at a low speed and kick into a high speed after one second. By that time, the demate was completed. We later determined that we could demate the pin and socket with a single speed between 0.3 and 0.9 inches per second.

Data for the demate speed tests is shown in Figures 40-43 for 9/19/94. In Figure 40, the 1/0 AWG pin and socket carry 80A at 32V. At a high speed demate of 0.9 inches/second, the arc is sustained for a distance of 0.14 inches. The arc voltage and current for these tests in Figure 40-43 were typically 15V and forty amps for a power level of 1300-1600 watts dissipated in the arc.

In Figure 41, the demate speed is 0.3 inches/second and the arcing distance is 0.13 inches. The distance over which the arc is sustained had no appreciable change with demate speed.

In Figure 42, the current had been increased from 80A to 100A, a 25% increase in current. The arc distance is measured to be about one third longer than for the 80A case, or 0.17".

In Figure 43, the demate began with the pin and socket only making enough contact to maintain the 100A of current in the circuit. In all previous tests, the pin was fully inserted into the socket.

No arc was sustained in the test, although the current spike at demate was large, 180 amperes.

The data in Figure 43 indicates that the arc is not necessarily initiated just at the final separation of the pin and socket. In some video frames of other tests, the arc seems to be inside the socket as the pin emerges from it. Additional tests may be done in the future to clarify this point by inserting the pin to various depths in the socket before demating.

One possible mechanism for initiation of the arc is the large change in current density as demate occurs. While the pin is fully seated, there is a uniform current density from the wire to the socket and to the pin. As the pin begins to retract, the current density in

the socket is zero in the voided region of the socket and significantly higher in the corresponding portion of the socket shell. As the pin emerges from the segmented inner section of the socket, which had been forced radially outward, against the outer shell of the socket by the pin, it oscillates due to the rapid removal of the radial force. As a result, there may be only a small number of these sections carrying the 100A of current density. One of these oscillating segments could be making and breaking contacts and thus striking the arc.

When we took the data in Figure 43, we did not force the pin far into the socket; it was only pushed to the edge of the socket enough to carry 100A. The pin never went in deep enough to compress the inner sections and so they did not oscillate on the demate.

VII. Temperature Tests

The 1/0 AWG pin and mated socket was allowed to carry 80 amperes for an extended period of time and a thermocouple used to give the temperature use under vacuum. This data is shown in Figure 44. The temperature curve indicates that over a much longer period of time, the temperature could rise to 150^{o} F.

Without allowing the system to cool, the current was raised to 100A. Figure 45 shows that the ultimate current would be about 180^{o} F.

The thermocouple in the above tests positioned about six inches from the socket and taped to the surface of the silicon insulation. Neither of the above temperatures, 150^{o} F and 180^{o} F, are excessive for this wire and insulation but we did not try to simulate the 1/0 wire being bundled up tightly with other wire. Our tests involved only a single 1/0 wire in the chamber at 5×10^{-5} Torr.

One curious piece of data for the temperature tests occurred when we did a demate at 80 and 100A.

The data in Figure 42 shows a large current spike when the discharge died out.

In Figure 43, the temperature was 180^{o} F when we did the demate. Even though there was no discharge, the current spike was significant. In other data runs, current spikes at the termination of the discharge were present, but much less prominent.

LIST OF ILLUSTRATIONS

FIGURES

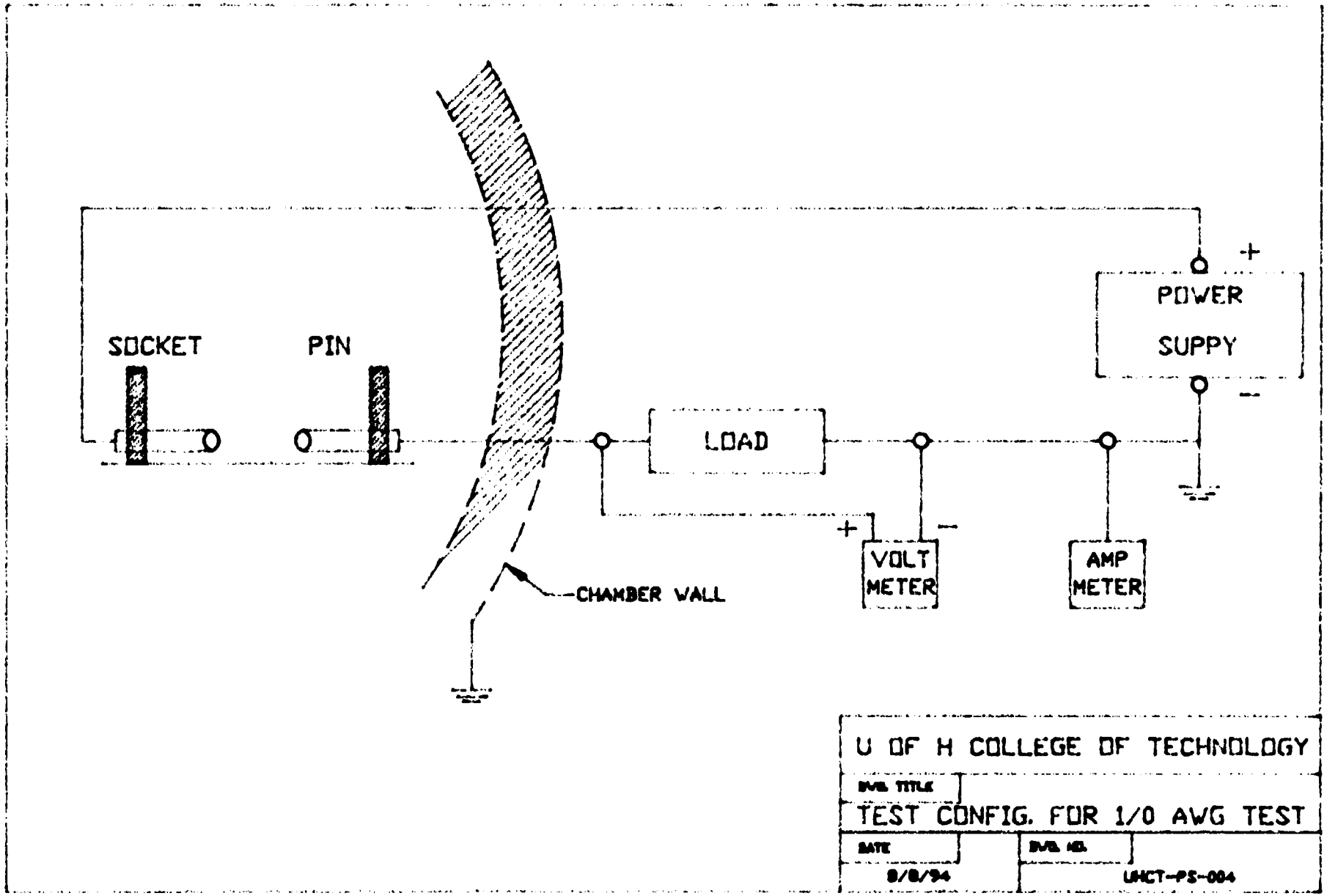

SOCKET
PIN
CHAMBER WALL
LOAD
VOLT METER
AMP METER
POWER SUPPY
+
-
+
-
U OF H COLLEGE OF TECHNOLOGY
TEST CONFIG. FOR 1/0 AWG TEST
8/8/94
UHCT-PS-004

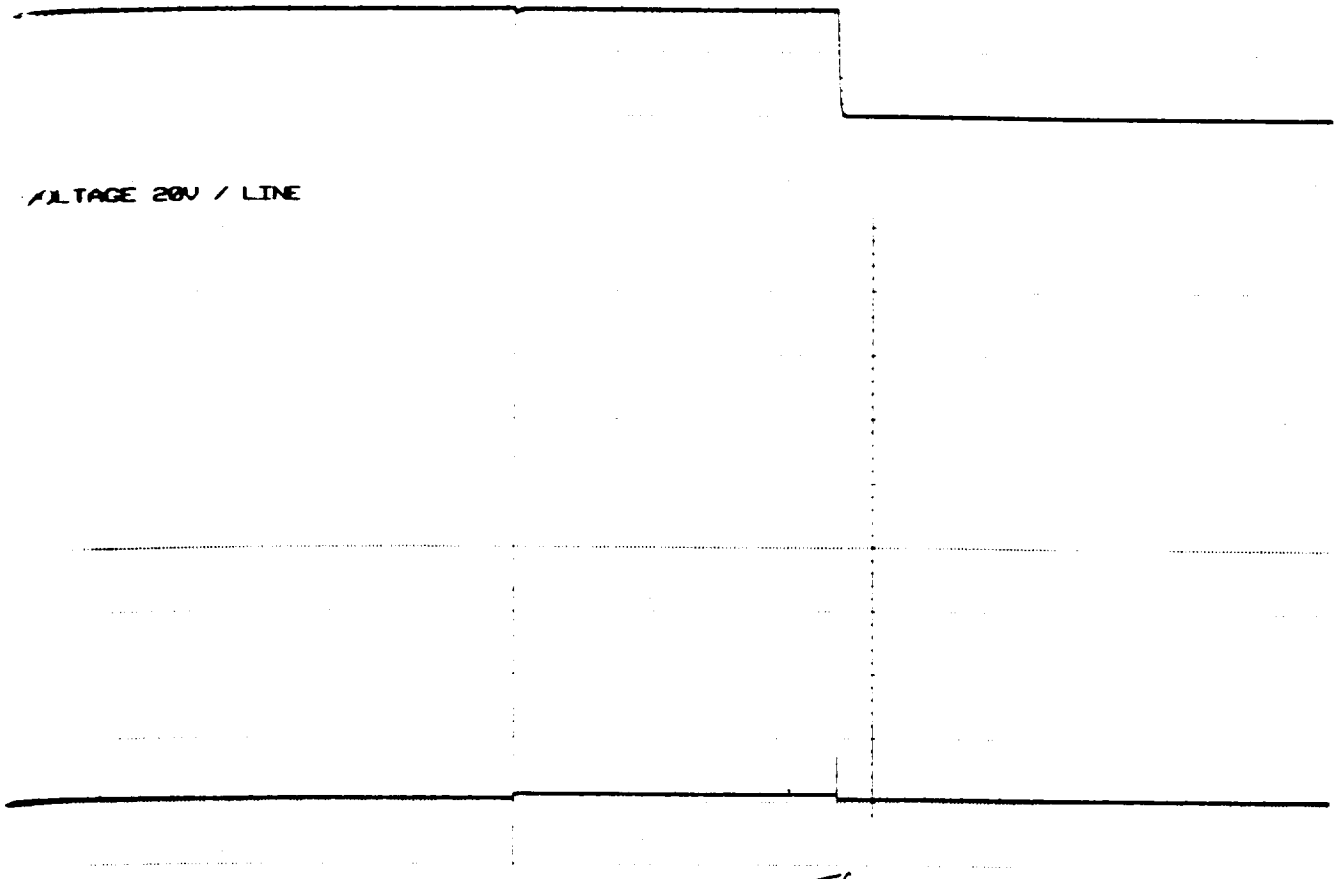
Figure 1

NASA - PIN & SOCKET TABLE

Pin & Socket Gage	dc Current 50% Max. (amps)	dc Current l00% Mas. (amps)	DC Current l25% Max. (amps)
8	45	90	112.5
12	14.8	29.5	36.9
16	9.3	18.5	23.1
20	6.5	13	16.3
22	4.3	8.5	10.6

Figure 2

TEST 37V
1.5A
22gA Powered socket



Arc Demote

1.

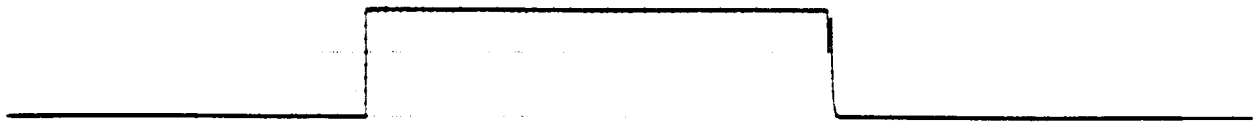
Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

Figure 3

1:18:41 •13 JUL 94 •SPD: 5 MM/S •TIME SCALE 200.0 MS/ MM •ANALOG REAL TIME

33V
3.07A

22 gage power socket
Remote



LTAGE 20V / LINE

RRENT 20A / LINE

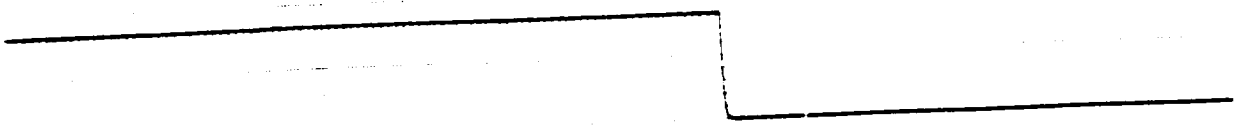
Remote

Astro-Med, Inc.

MT-95000 MULTI-TASK RECORDER

Figure 4

22- 33 / 3,8 D



LOAD VOLTAGE 20V / LINE

LOAD CURRENT 20A / LINE

LTI-TASK RECORDER

Astro-Me

Figure 5

33V 10.6

22 gA (return)

Run 7

22 – 33/10.6 D

Ru

repeat

22 C
0

D VOLTAGE 20V / LINE

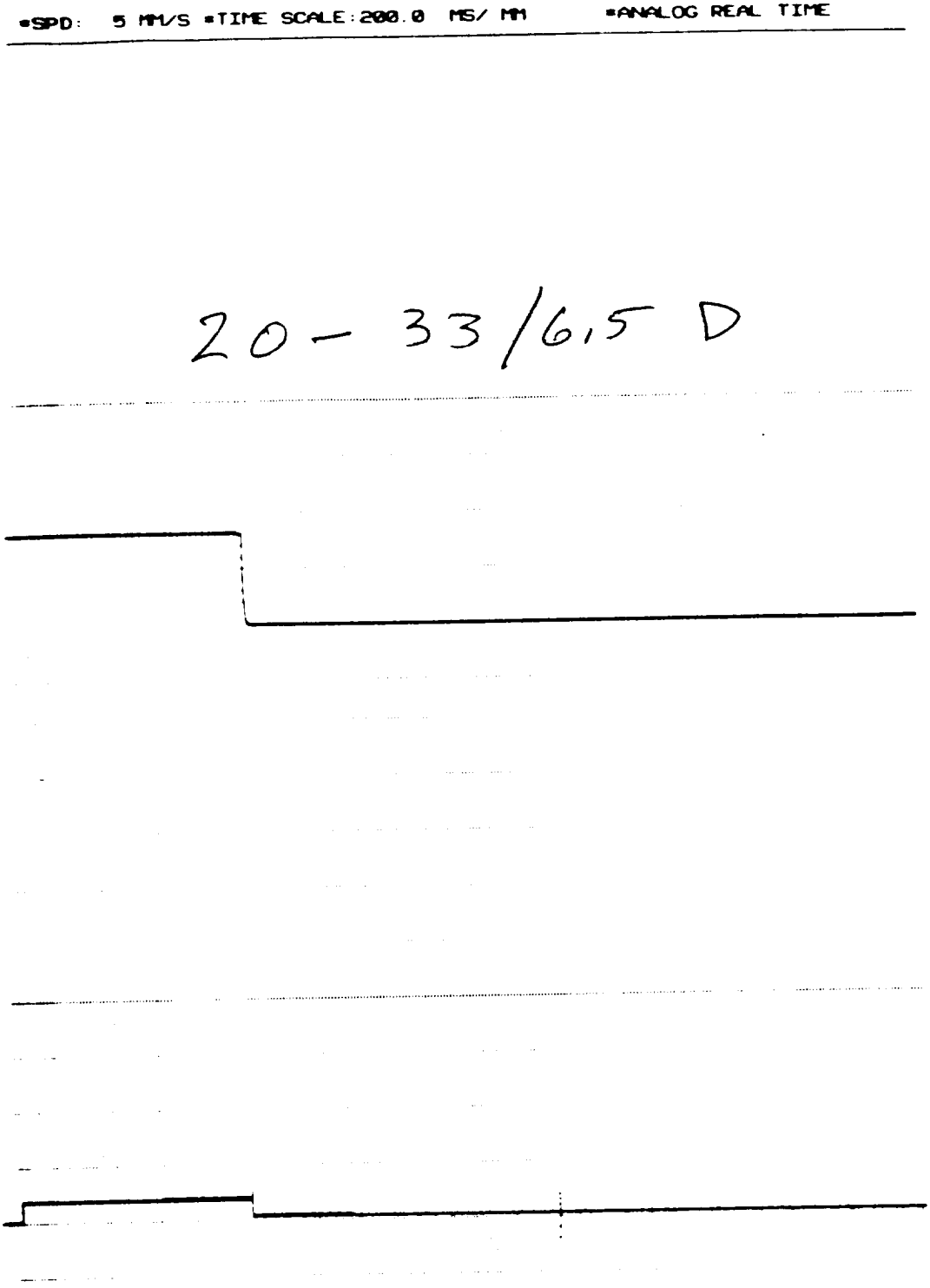
recent
robe
t turned on

D CURRENT 20A / LINE

1

Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

Figure 6

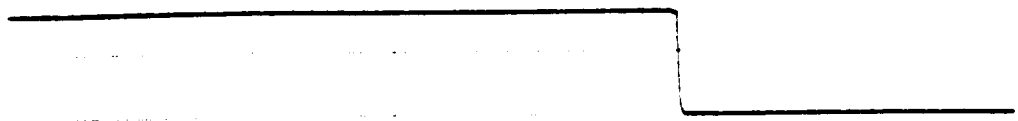


Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

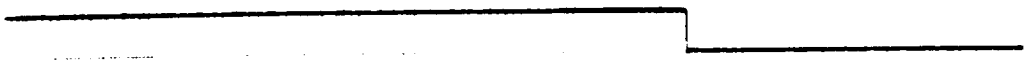
Figure 7

12:36:46 •13 JUL 94 •SPD: 5 MM/S •TIME SCALE:200.0 MS/ MM

20 gm 33V 13A



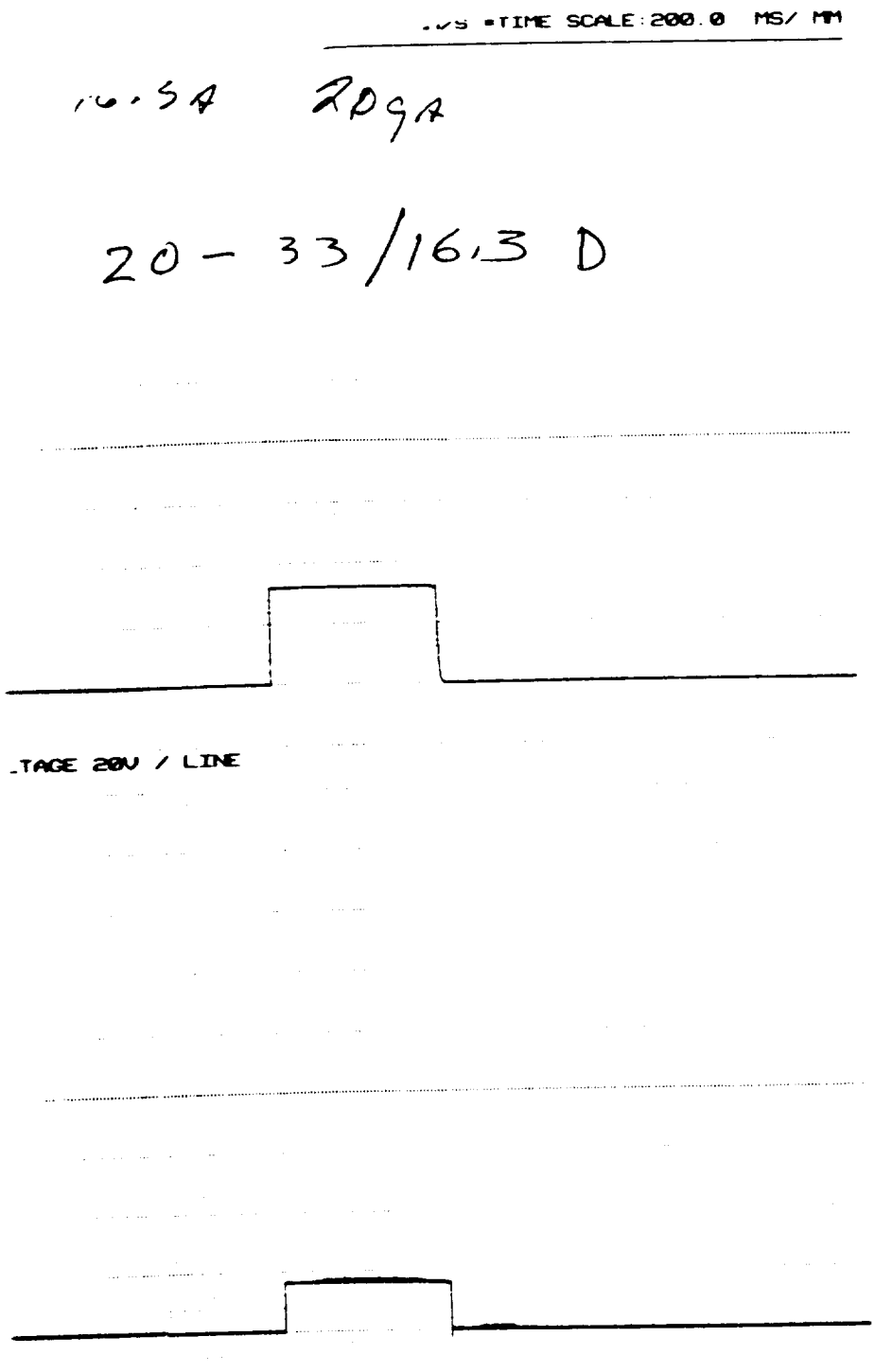
D VOLTAGE 20V / LINE



ND CURRENT 20A / LINE

Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

Figure 8

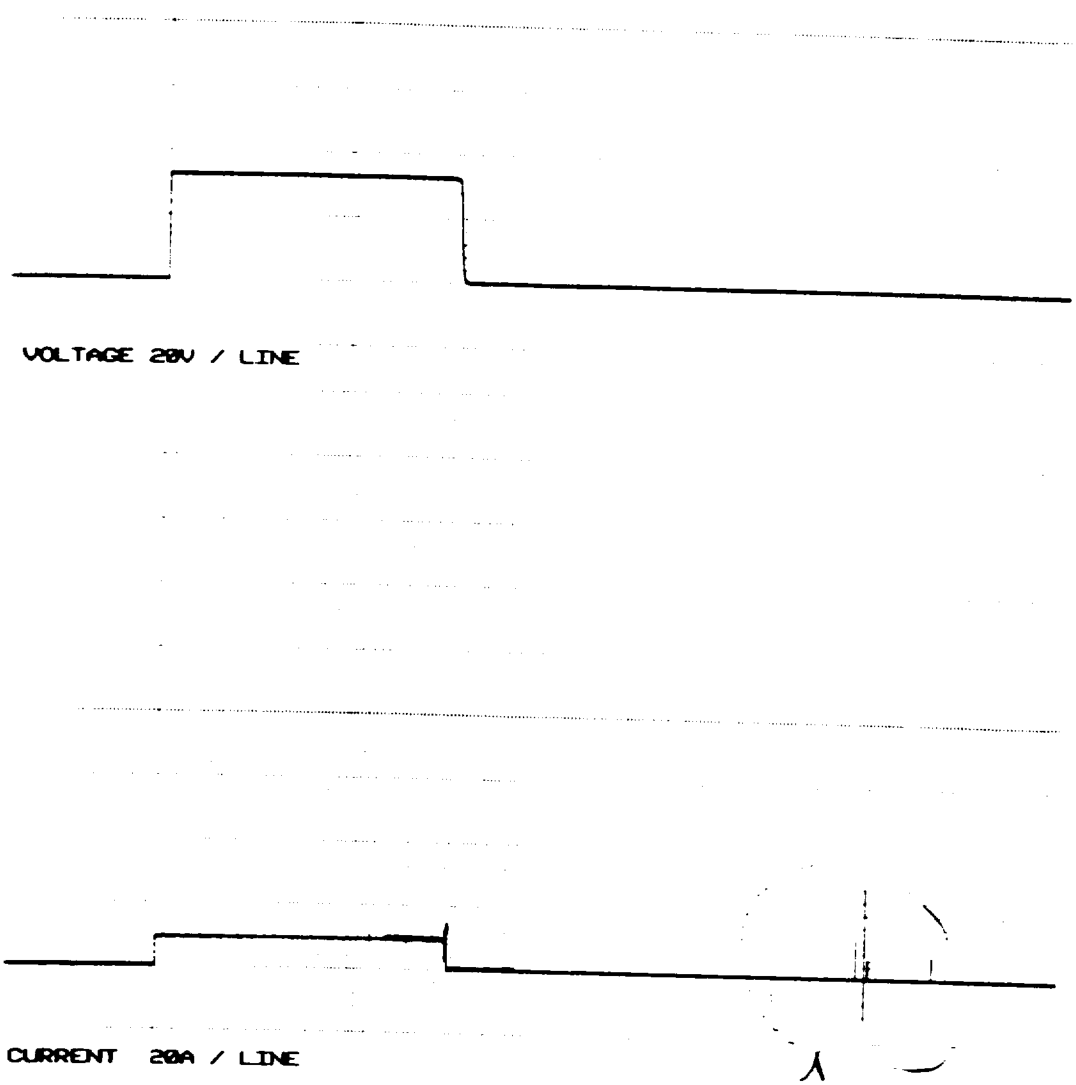


Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

Figure 9

14:22:00 *13 JUL 94 *SPD: 5 MM/S *TIME SCALE:200.0 MS/ MM

169A
33V 9,3A



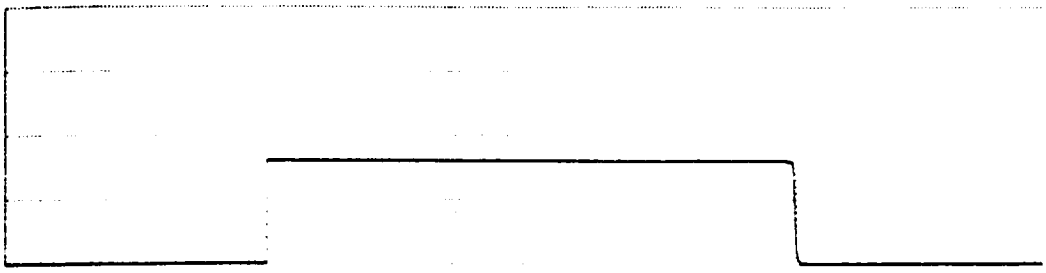
Astro·Med, Inc. MT-95000 MULTI-TASK RECORDER

Power Supply
Plasma Source
turned off

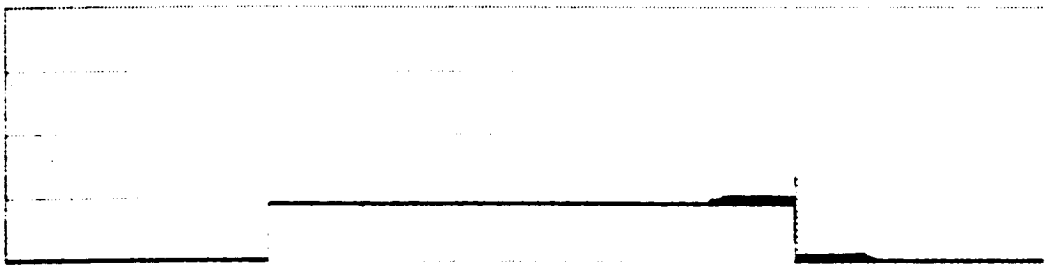
Figure 10

< 14:41:23 =13 JUL 94 =SPD: 5 MM/S =TIME SCALE:200.0 MS/ MM

33V 18.5A 16 GA



LOAD VOLTAGE 20V / LINE



LOAD CURRENT 20A / LINE

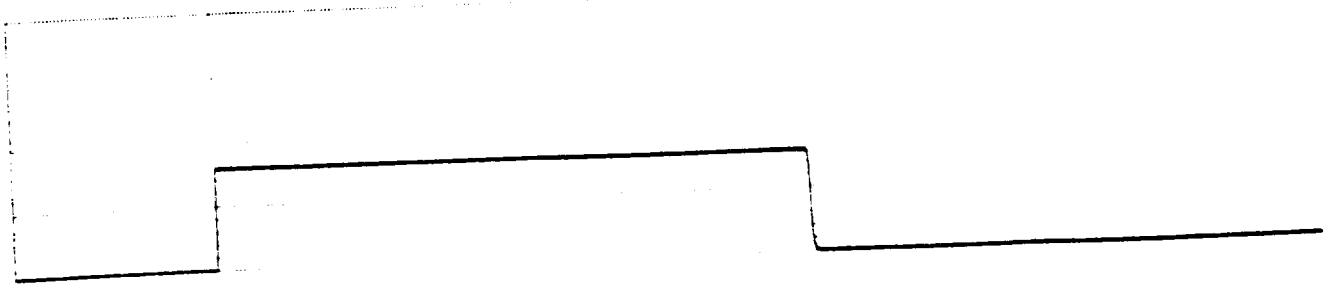
Astro-Med, Inc.

MT-95000 MULTI-TASK RECOR

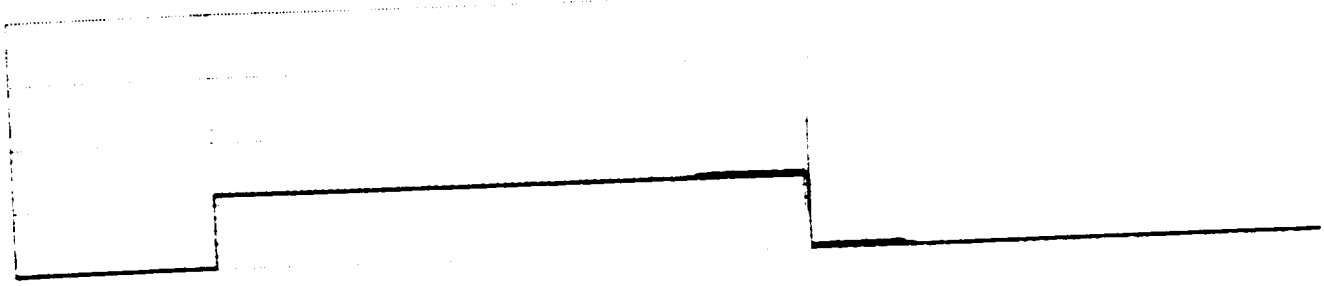
Figure 11

< 15:03:09 •13 JUL 94 •SPD 5 MM/S •TIME SCALE 200.0 MS/ MM

33V 23.1A 16.9A



LOAD VOLTAGE 20V / LINE

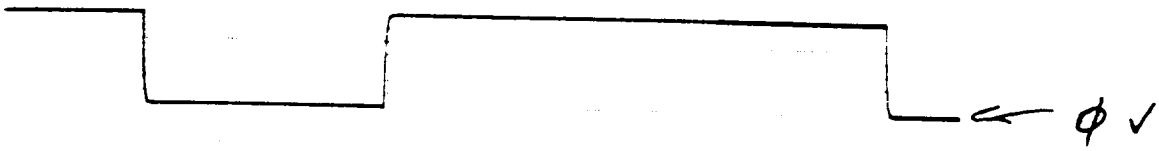


LOAD CURRENT 20A / LINE

Figure 12

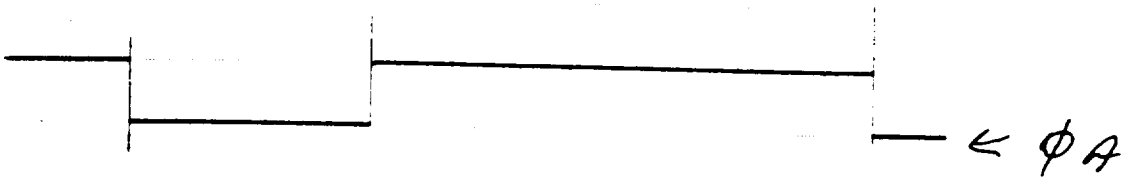
Calibration Run
7/25/94

29.6V



/ LINE

20A



/ LINE

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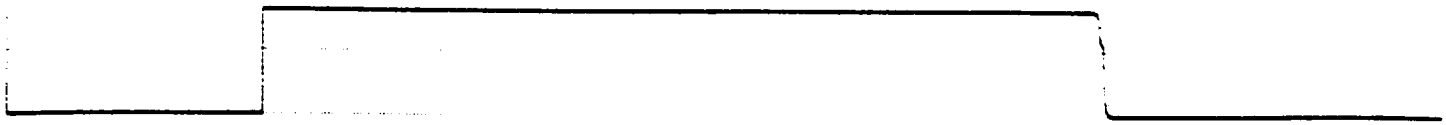
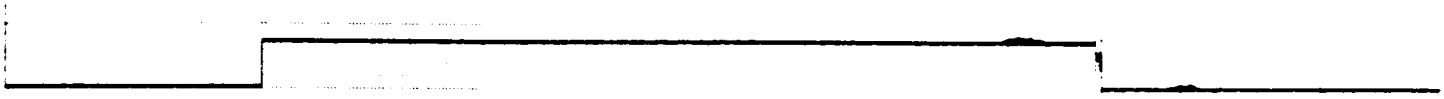
Figure 13

33V 14.8A

12 AWG



LOAD VOLTAGE 20V / LINE



LOAD CURRENT 20A / LINE

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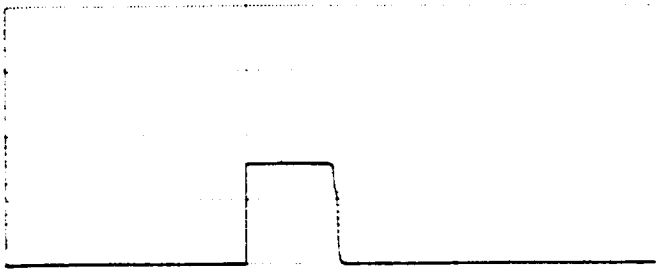
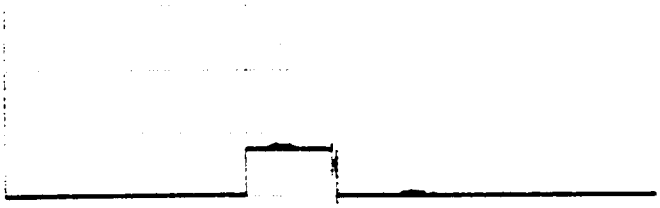
MT-95000 MULTI-TASK REC

Figure 14

12 gauge
32V 14.8A



LOAD VOLTAGE 20V / LINE

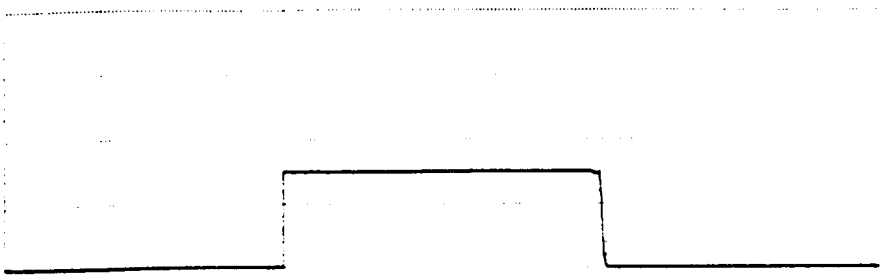


LOAD CURRENT 20A / LINE

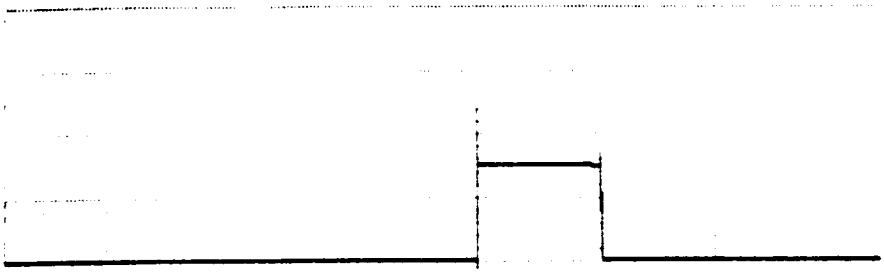
Figure 15

< 12:03:18 *25 JUL 94 *SPD: 5 MM/S *TIME SCALE:200

12 gauge
32V 29.5A
probe turned on



LOAD VOLTAGE 20V / LINE



LOAD CURRENT 20A / LINE

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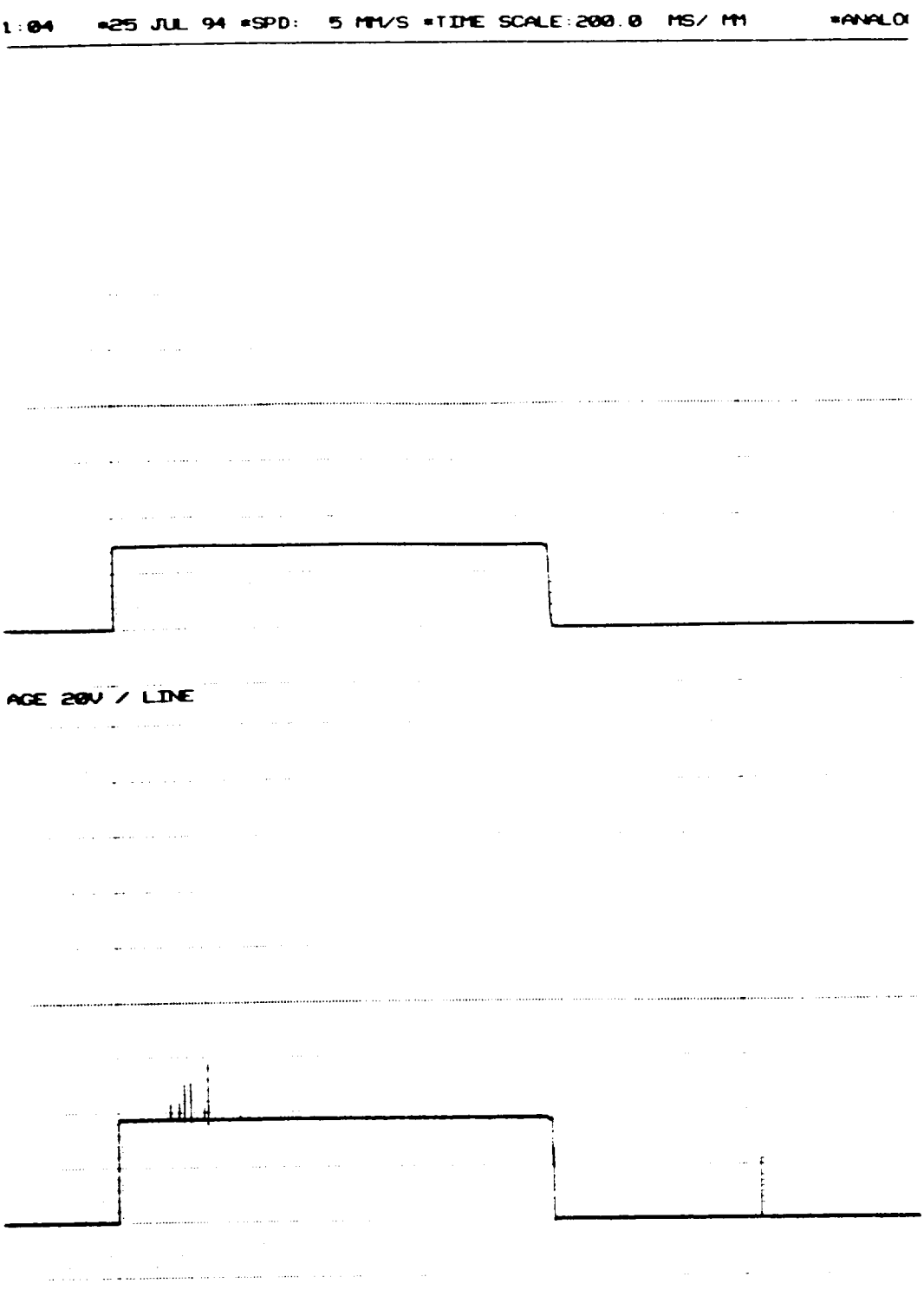
MT-95000 MULTI-TASK RECORDE

Figure 16



Rogauge
32V
36.9A

Plasma Furnace on

Figure 17

8 gauge
32V 45A

Figure 18

13:39:00 •25 JUL 94 •SPD 5 MM/S •TIME SCALE 200 0

8 gauge
32 v 90 A

VOLTAGE 20V / LINE

Current probe
Not turned on

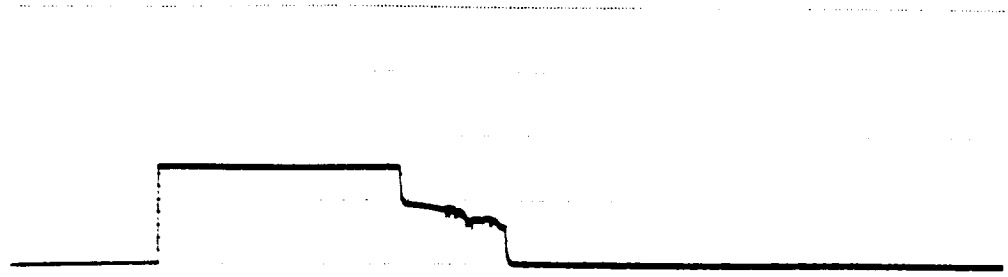
D CURRENT 20A / LINE

Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

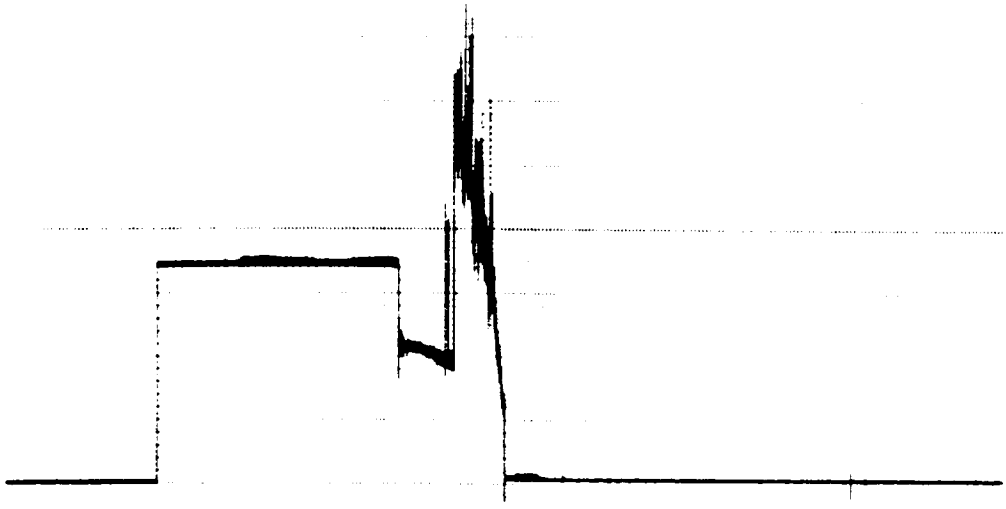
Figure 19

14:57:08 •25 JUL 94 •SPD: 5 MM/S •TIME SCALE:200.0 MS/ MM

Range
32V 60A



D VOLTAGE 20V / LINE



D CURRENT 20A / LINE

Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

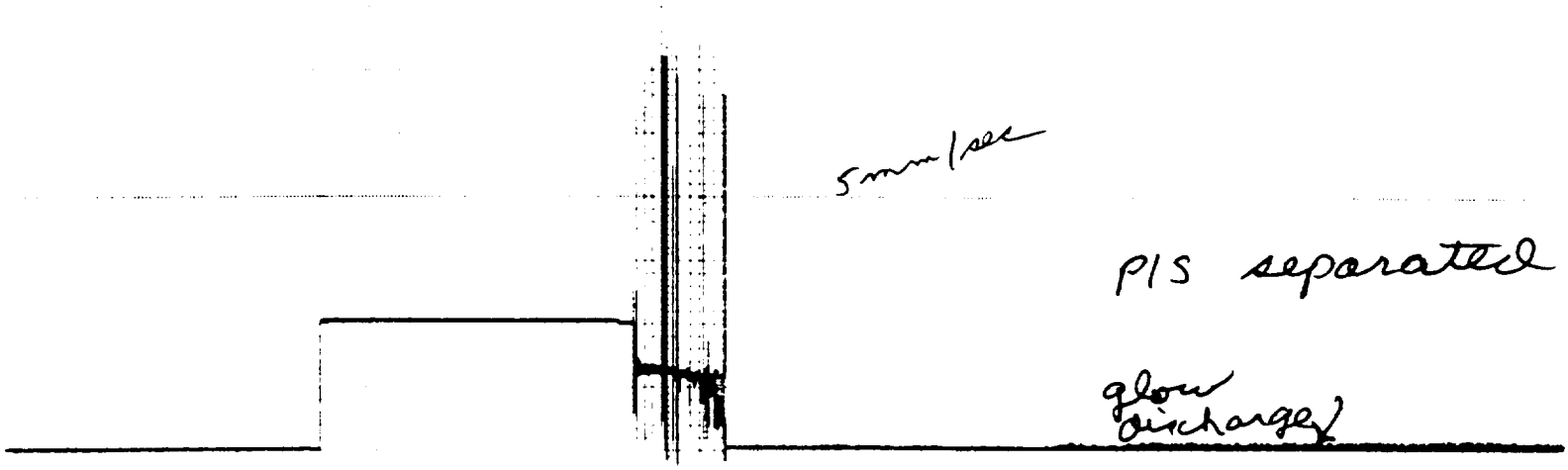
Figure 20

Run 1 8/3/94
8 AWG P/S
Powered socket

32V / 40A

sustained arc (10-17 V arc)

E 20V / LINE



T 20A / LINE

Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

Figure 21

8-32/30D
Run 2
Powered socket
8 AWG
8/3/94

32V
30A

OLTAGE 20V / LINE

slight
arc

discharge in socket???

or denote motor movement

URRENT 20A / LINE

Damage

Figure 22

LOAD VOLTAGE 20V / LINE

Run 2 to Part 3 mate dogs under power in chamber

for moving to remote

LOAD CURRENT 20A / LINE

63 MATE

Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

Figure 23

GROUND CURRENT 20A / LINE

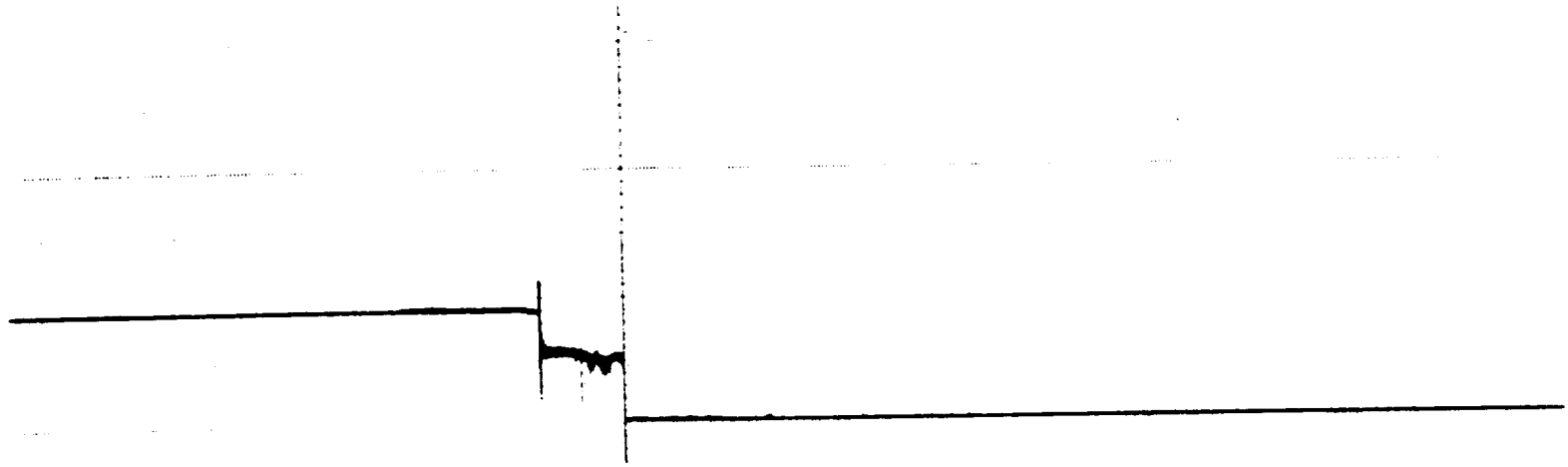
10 20 04 •03 AUG 94 •SPD 5 MM/S •TIME SCALE 200.0 MS/ MM •ANALOG REAL TIME

72V
5A

Run 3 8/3/94
8-32/35D

sustained arc

•AD VOLTAGE 20V / LINE



DAD CURRENT 20A / LINE

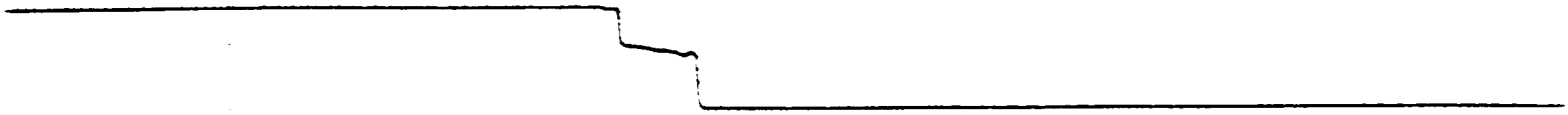
Dempsey

Astro-Med, Inc. MT-95000 MULTI-TASK RECORDER

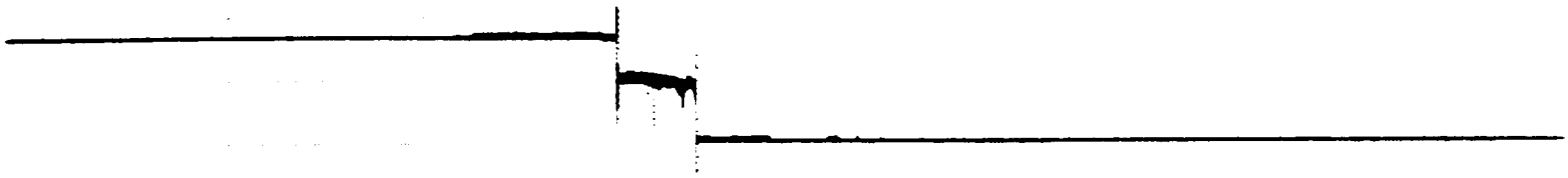
Figure 24

8/3/94
Run 4
8 - 32/32.5 D

sustained arc



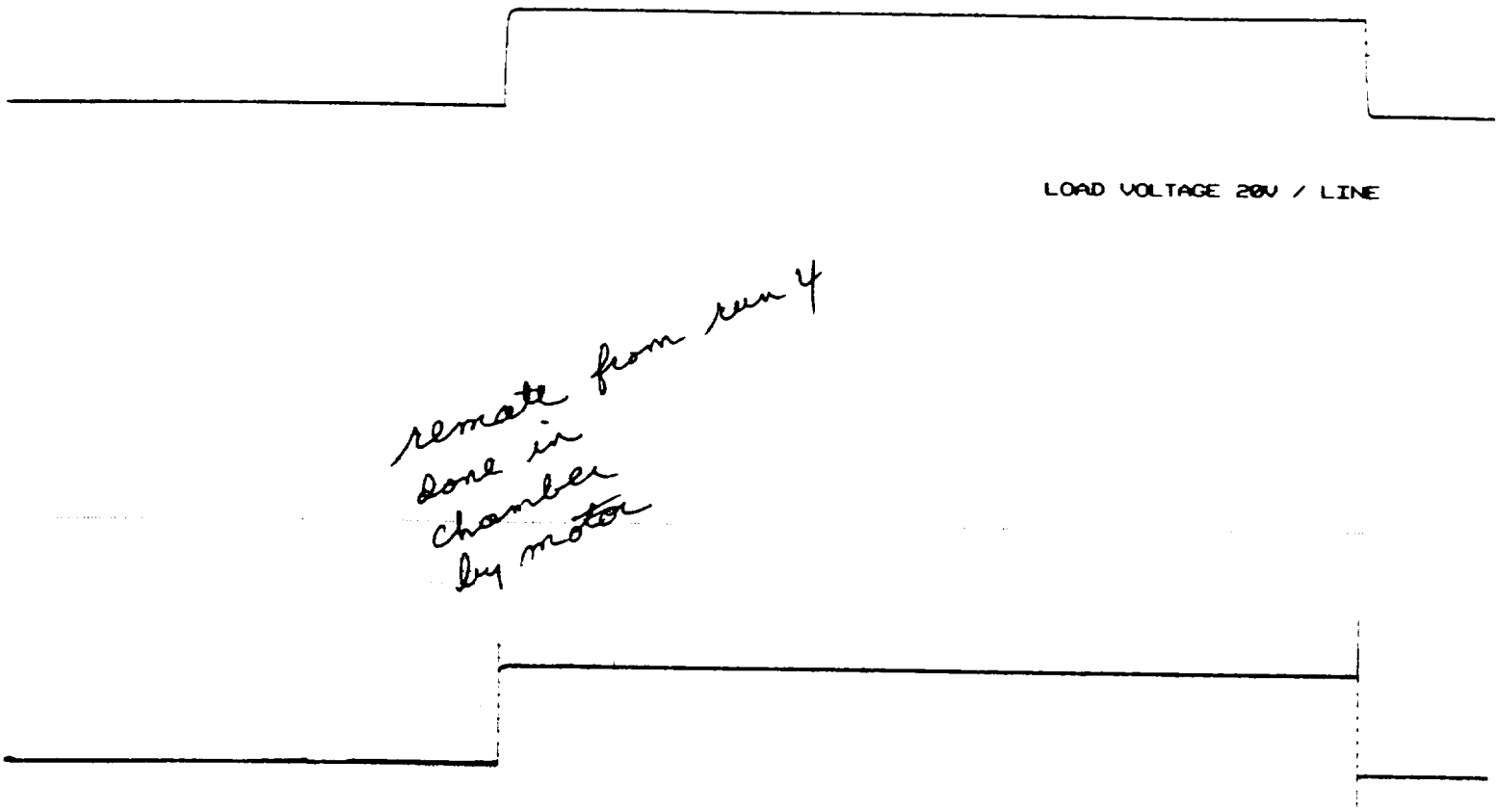
LINE



LINE

Dermatome

Figure 25



Remote Attempt

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5/5 board turned off

Figure 26

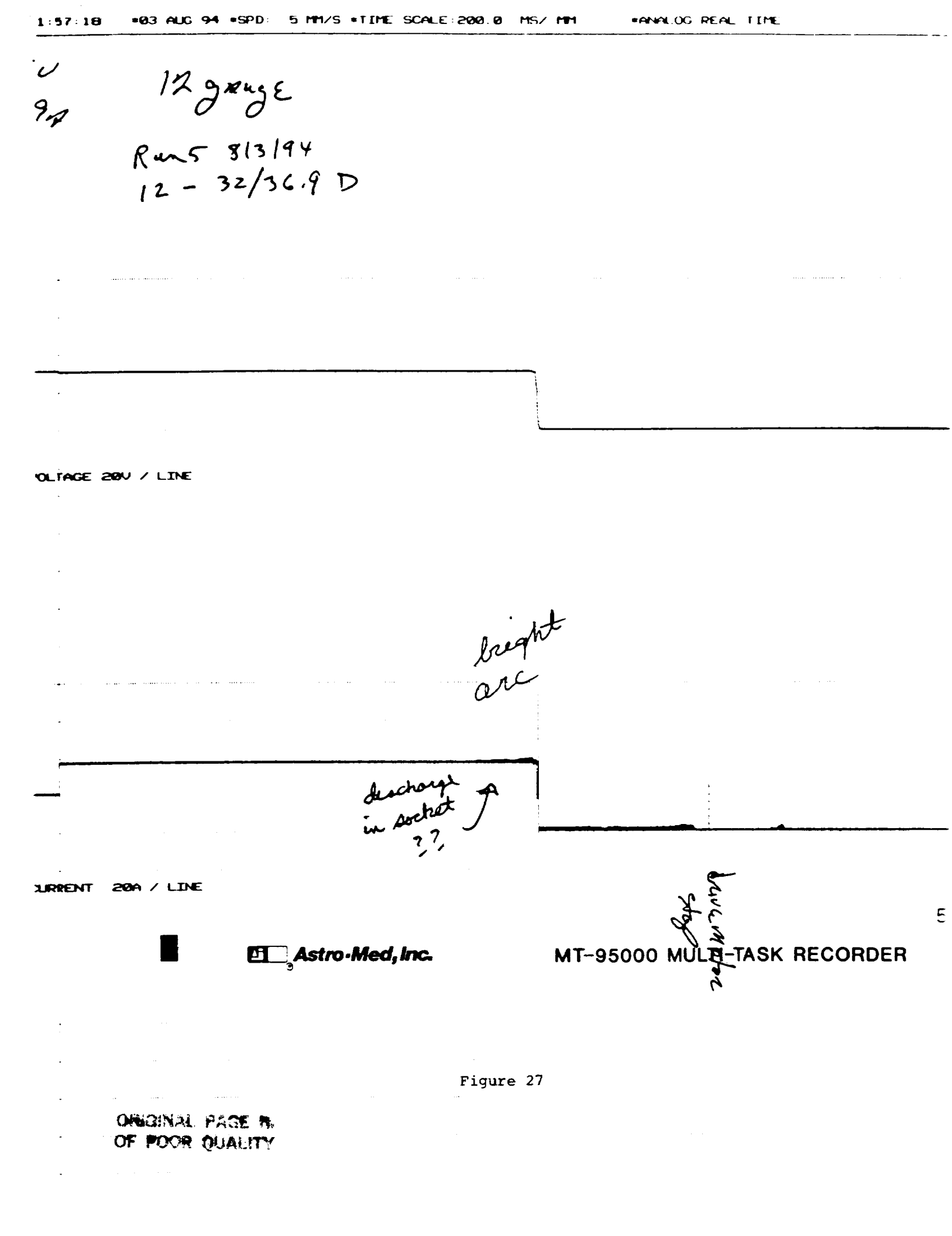

Figure 27

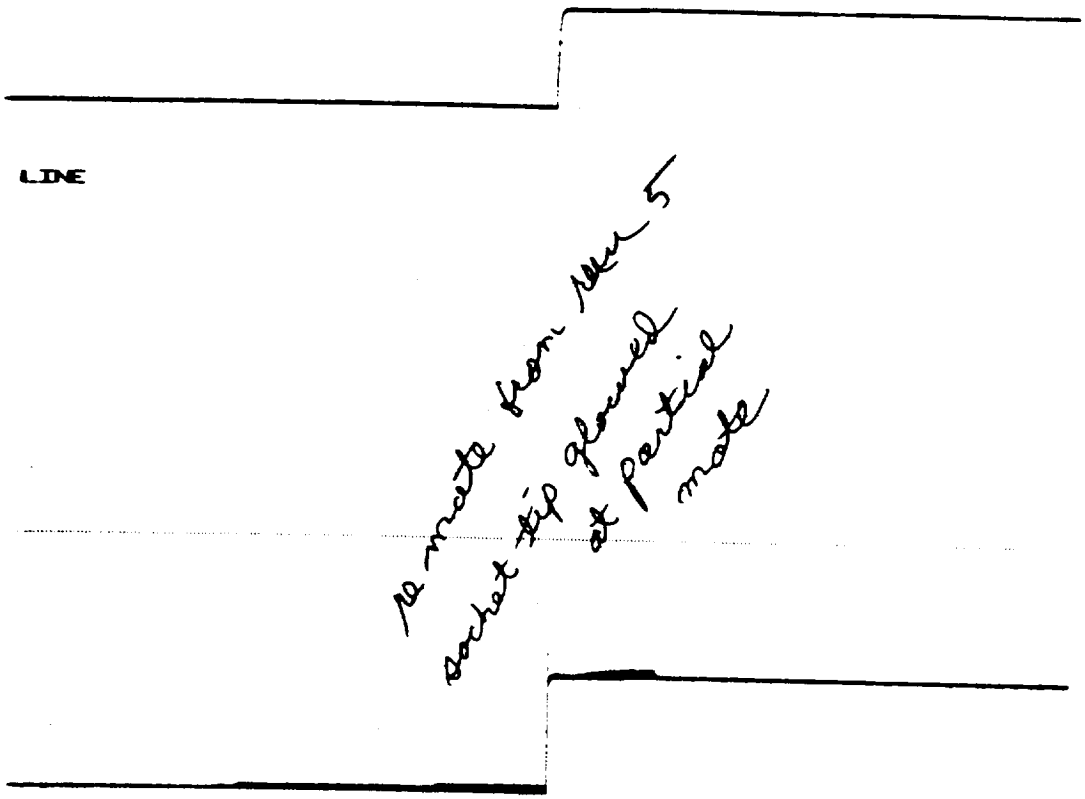

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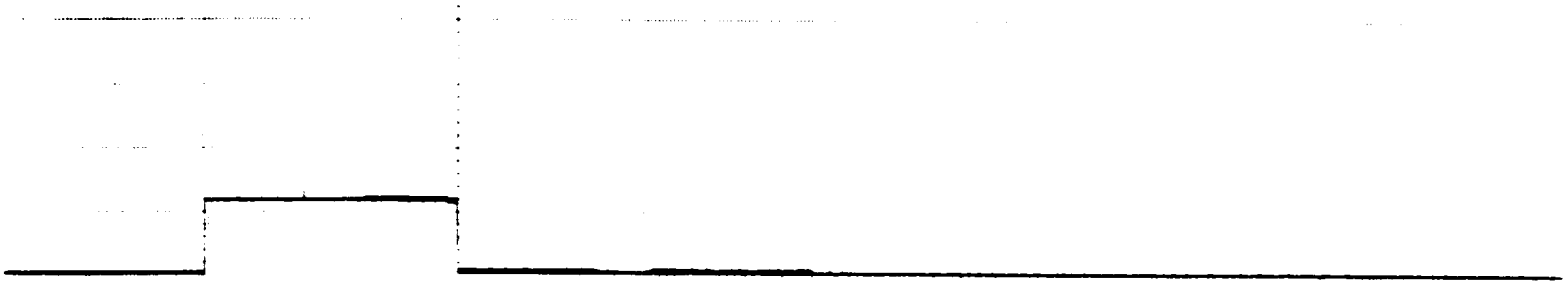
Figure 28

16 range
32V
23.1A

Run 6 8/3/94
16-32/23.1 D

VOLTAGE 20V / LINE



CURRENT 20A / LINE

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Figure 29

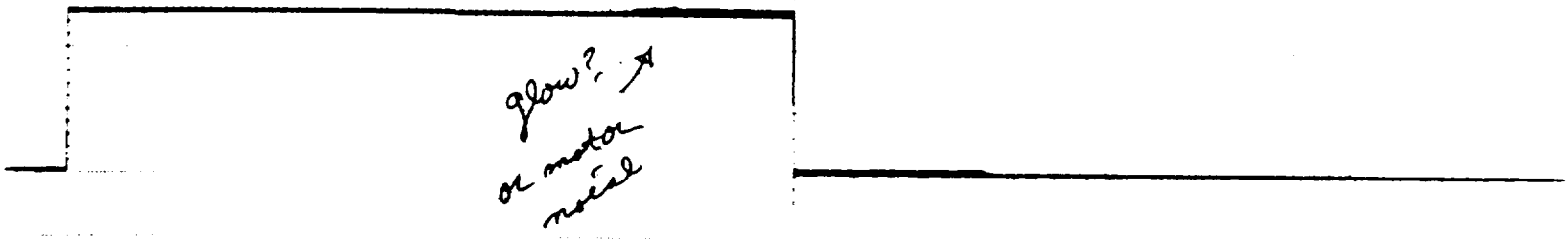
13:30:06 *03 AUG 94 *SPD: 5 MM/S *TIME SCALE:200.0 MS/ MM *ANALOG REAL TIME

1/0 gauge
32v 50A

Run 7 8/3/94
1/0 32/50 D

VOLTAGE 20V / LINE

slight arc



glow? ✗
or motor noise

CURRENT 20A / LINE

DEMATE

L

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Figure 30

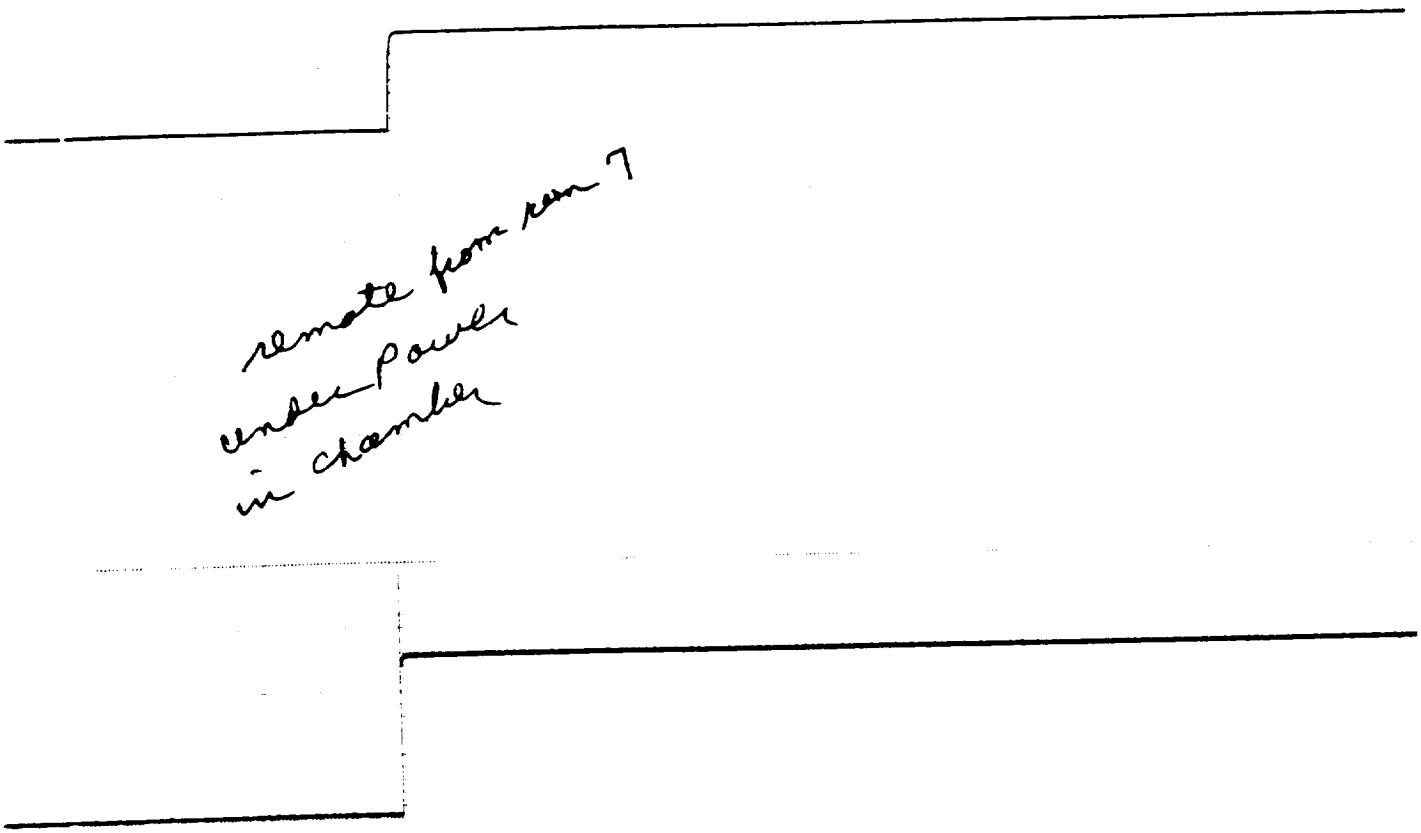

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Figure 31

Run 8 8/3/94
I/O 32/60 D

VOLTAGE 20V / LINE

) CURRENT 20A / LINE

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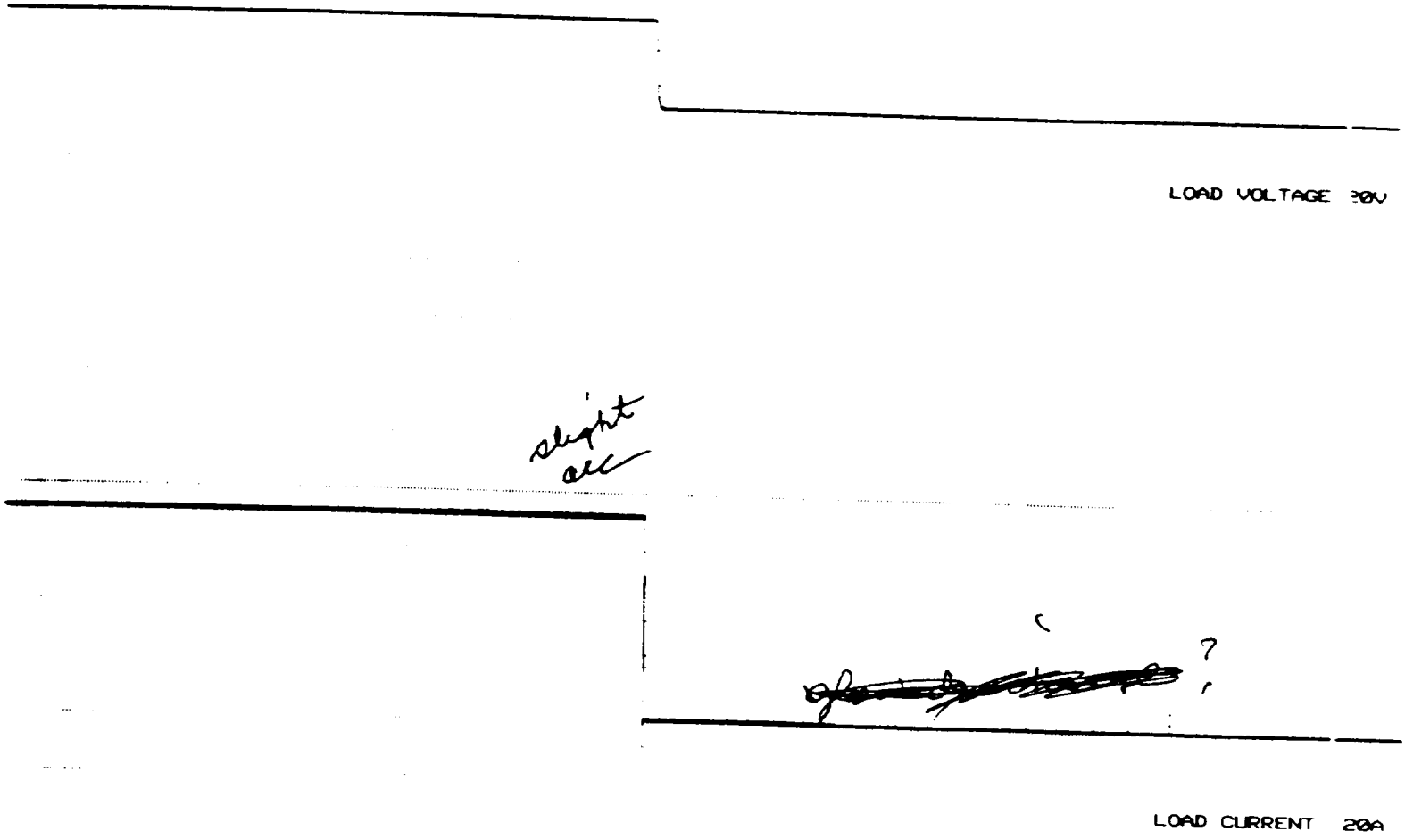
Figure 32

Run 9 8/3/94
1/0 32/50 D
70



tro-Med, Inc. MT-95000 MULTI-TASK RECORDER

Figure 33

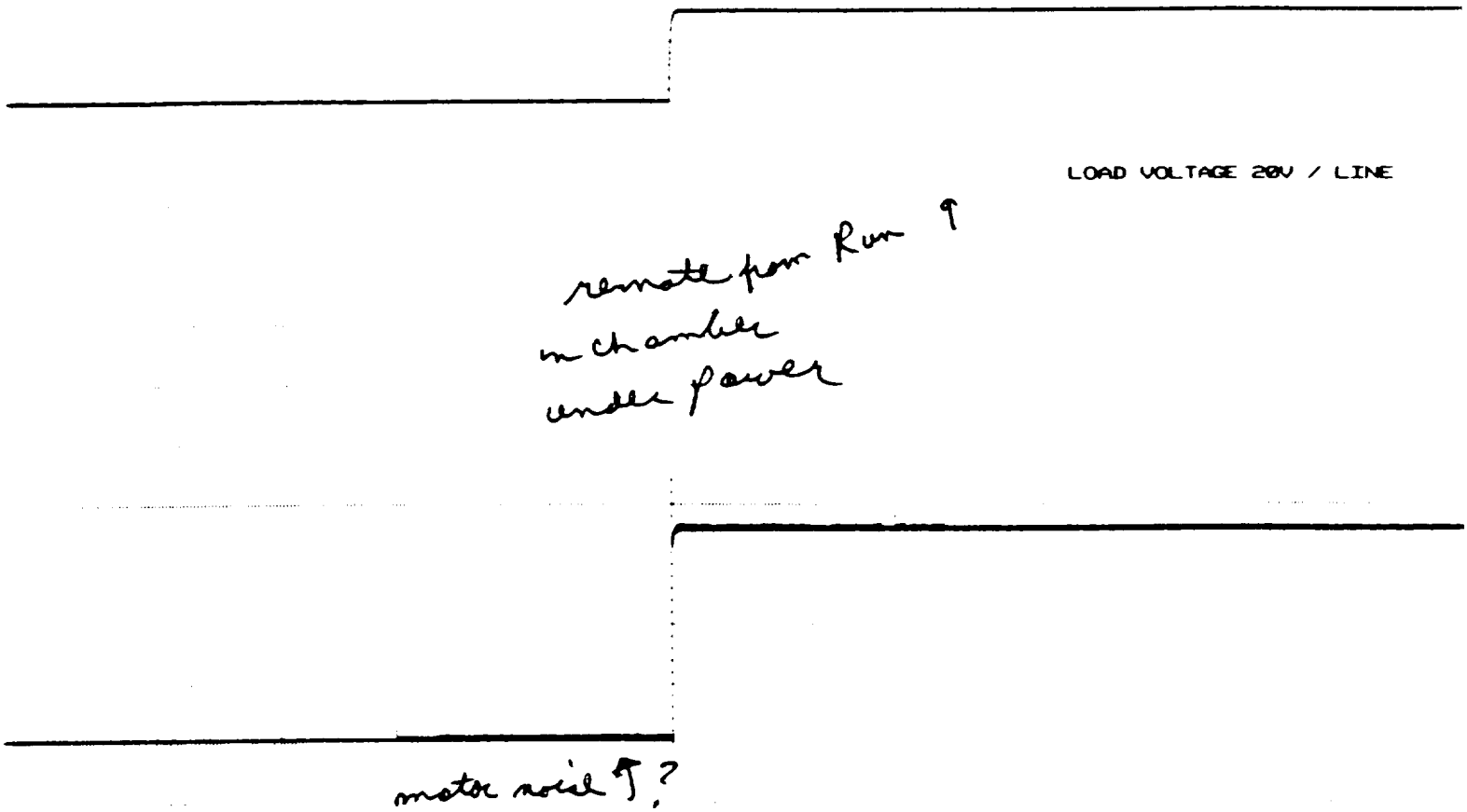


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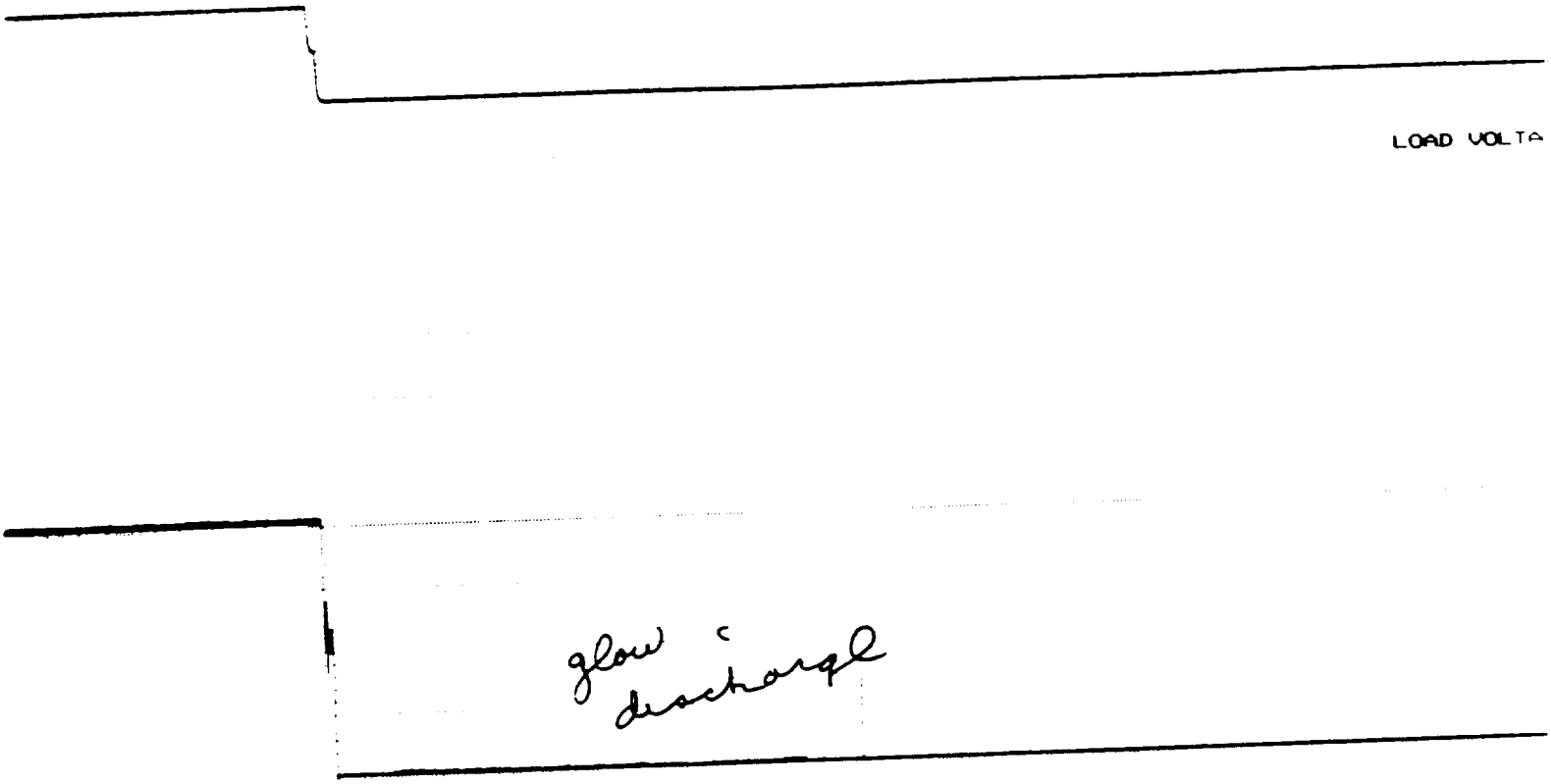
Figure 34

8A THRESHOLD FOR A SUSTAINED ARC AT 32VOLTS

Run 10 8/3/94
1/0 32/80 D
nearly a sustained arc



glow discharge

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Figure 35

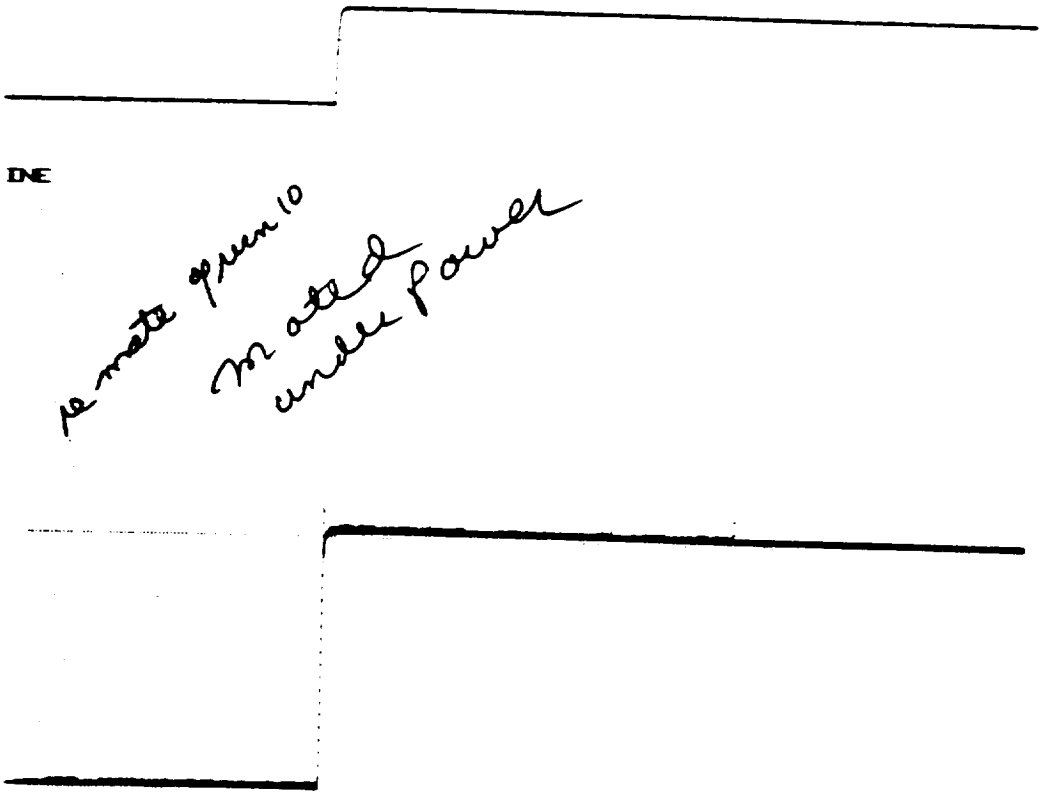

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Figure 36

20 90A 1/0 gauge

Run 11 8/3/94
1/0 32/90 D
nearly sustained arc

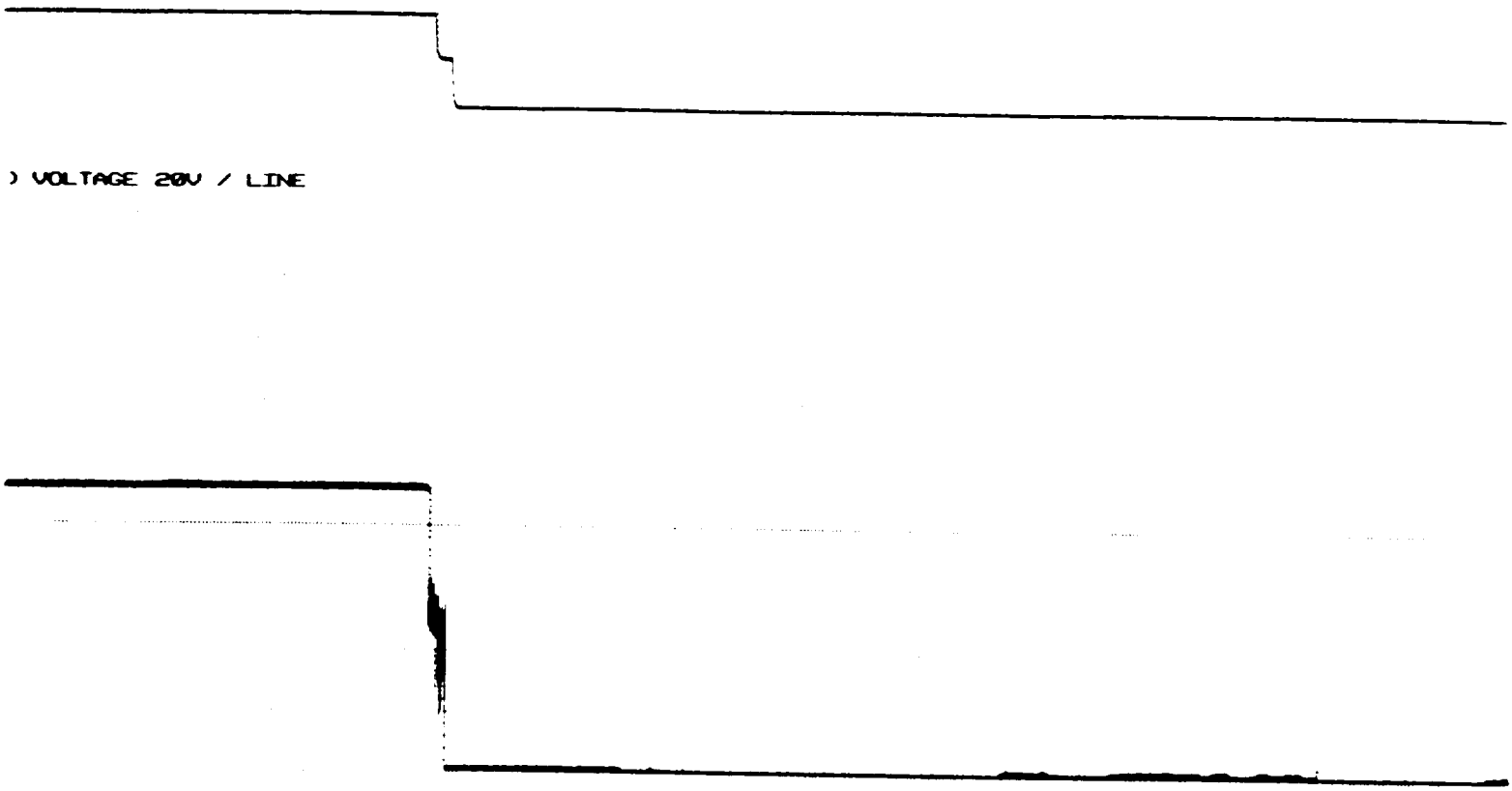

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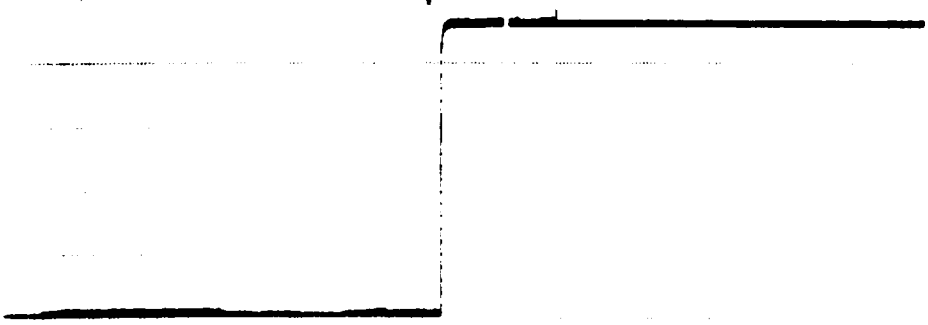
Figure 37

LOAD VOLTAGE :0V / LINE

remote of rear 11



LOAD CURRENT 20A / LINE

Figure 38

4.06.18 •03 AUG 94 •SPD: 5 MM/S •TIME SCALE:200.0 MS/ MM •ANALOG REAL TIME

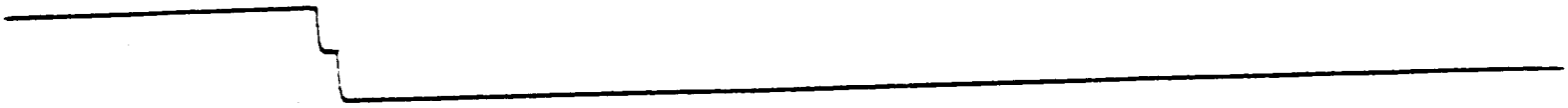
32V 100A 1/0 gauge

Run 12 8/3/94

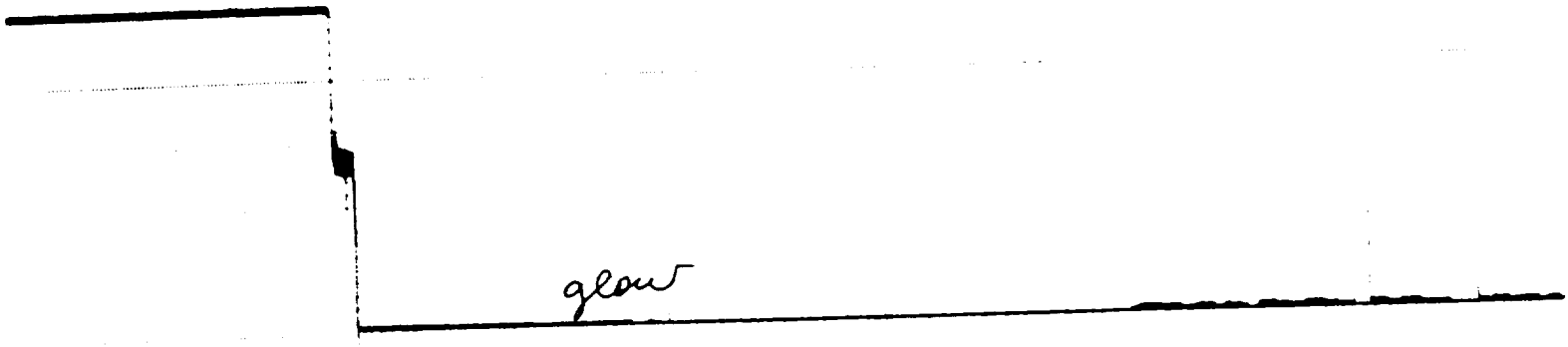
1/0 32/100 D

sustained

arc



VOLTAGE 20V / LINE



CURRENT 20A / LINE

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Pigure 39

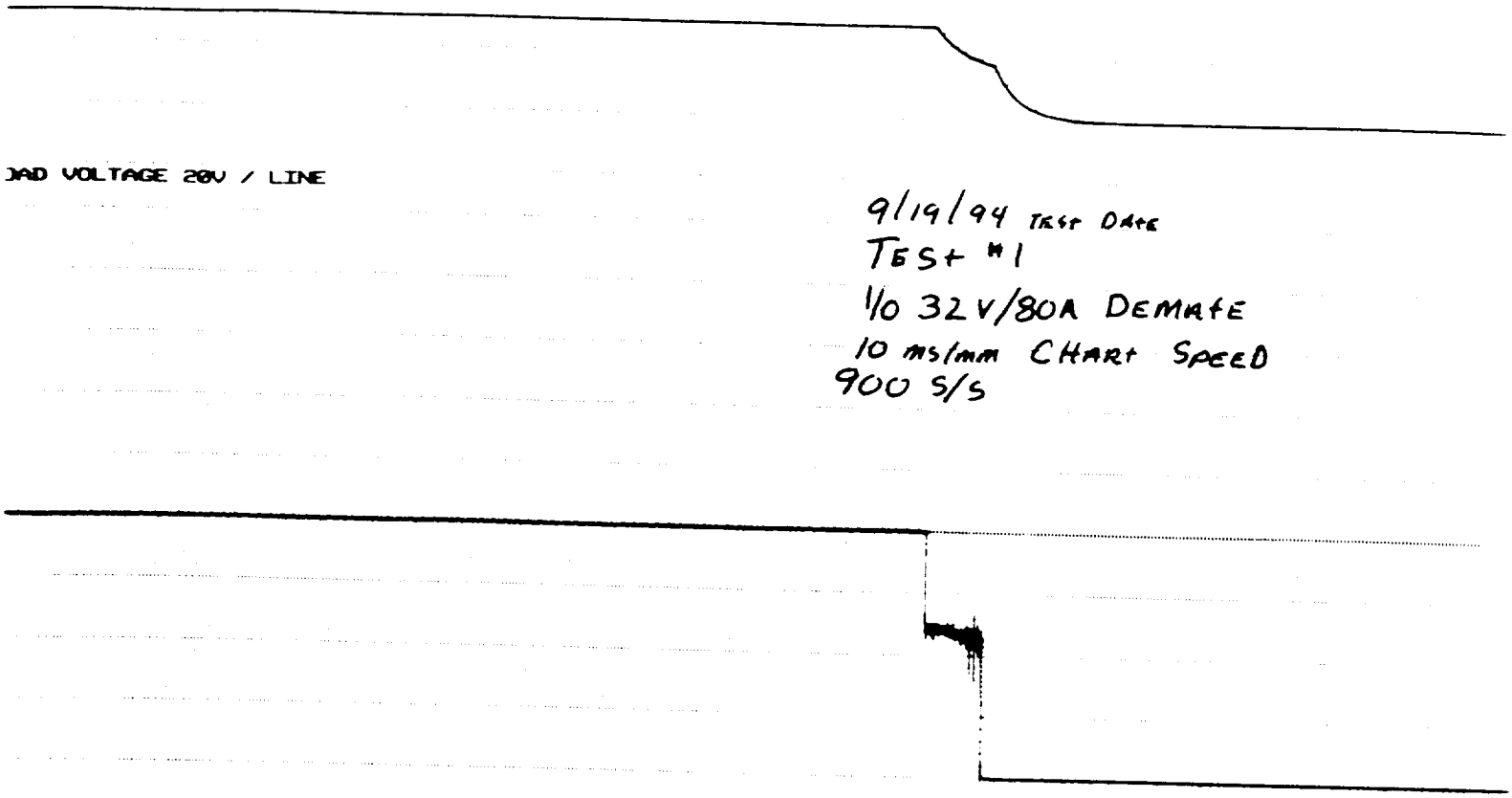

)AD VOLTAGE 20V / LINE
9/19/94 TEST DATE
TEST #1
1/0 32V/80A DEMATE
10 MS/MM CHART SPEED
900 S/S
)D CURRENT 20A / LINE
Astro-Med, Inc.
MT-95000 MULTI-TASK RECORDER

Figure 40

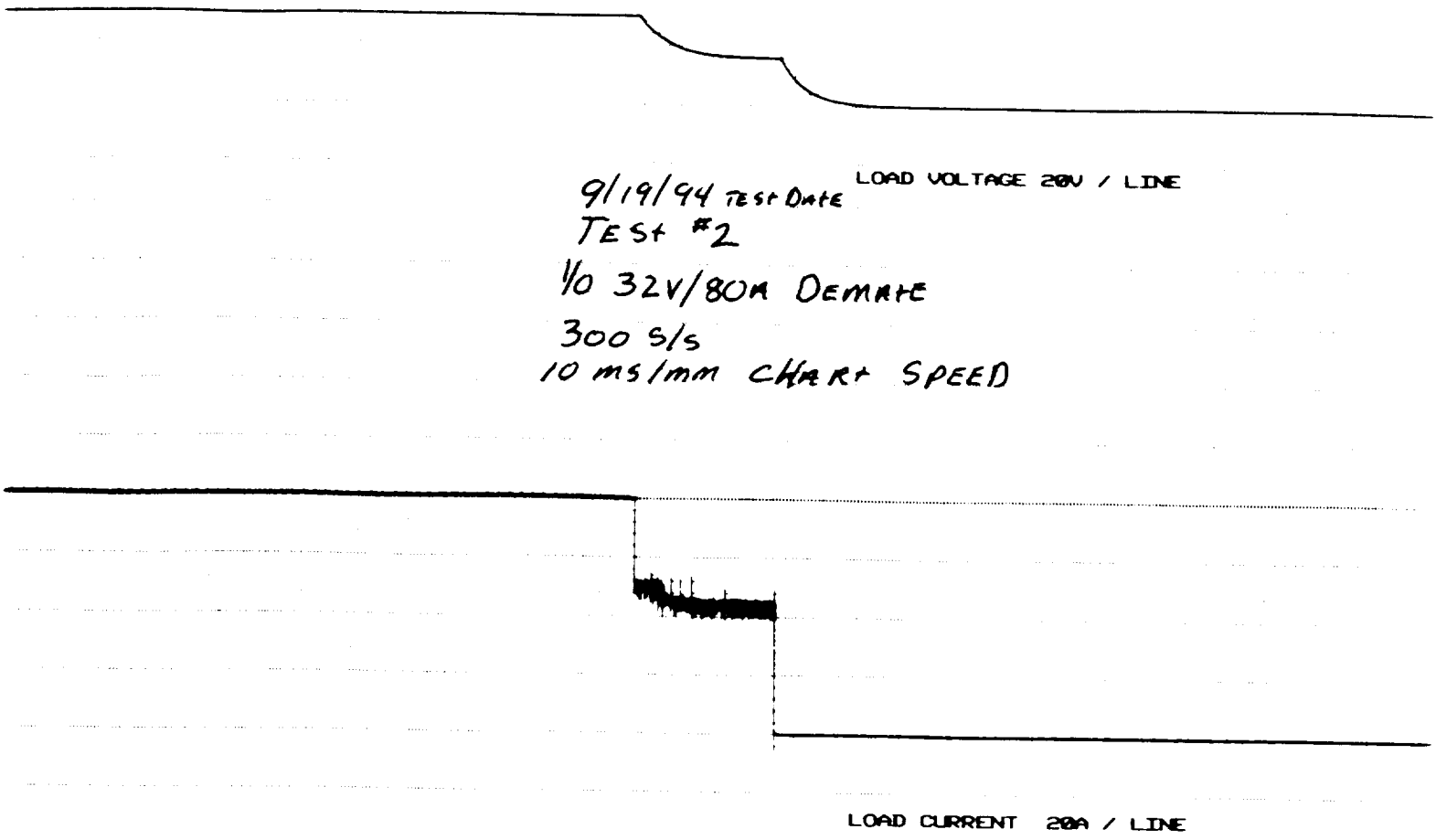
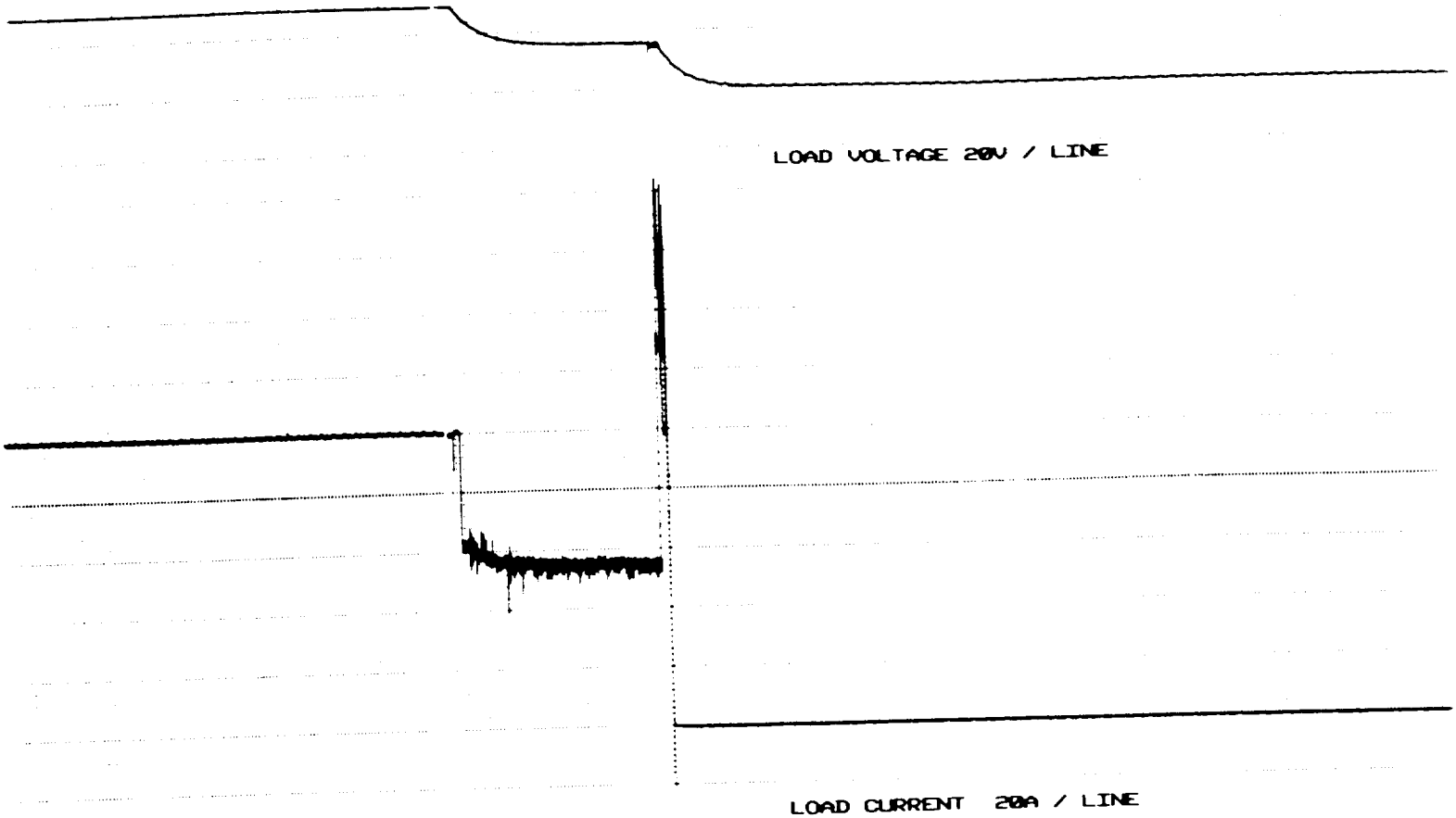

9/19/94 Test Date
LOAD VOLTAGE 20V / LINE
TEST #2
1/0 32V/80A DEMATE
300 S/S
10 MS/MM CHART SPEED
LOAD CURRENT 20A / LINE
465
Astro-Med, Inc.
MT-95000 MULTI-TASK RECORDER

Figure 41

9/19/94 TEST DATE
TEST #3
1/0 32V 100A DEMATE
10 ms/mm CHART SPEED
300 S/S TEMP 180°F



463

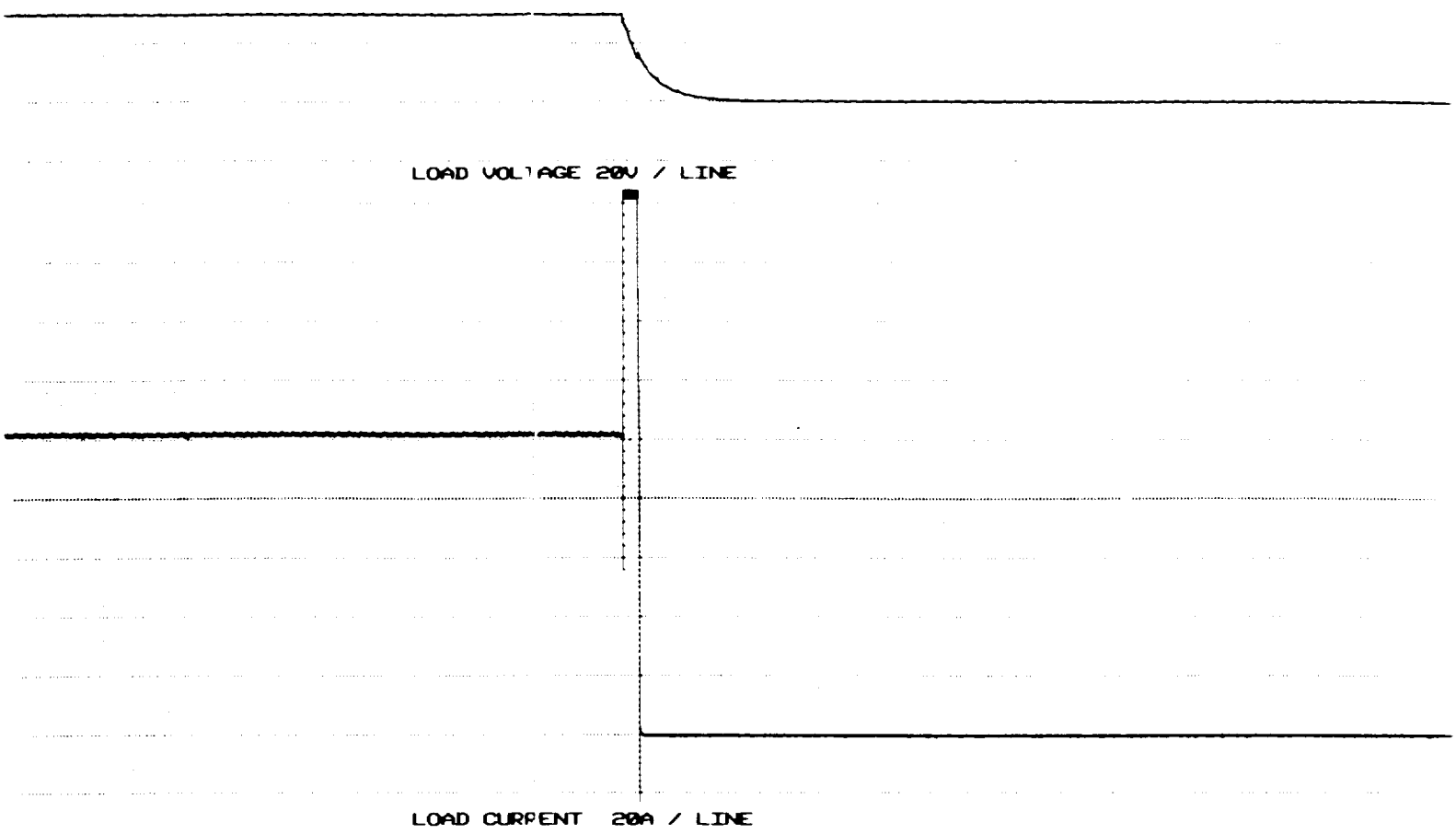
Astro-Med, Inc.

MT

R

Figure 42

9/19/94 TEST DATE
TEST #4
1/0 32V/100A DEMATE
10 ms/mm CHART SPEED
900 S/S TEMP. 180°F



461

RDER

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Figure 43

100 A 900 S/S
Δt = 50 ms
t varies

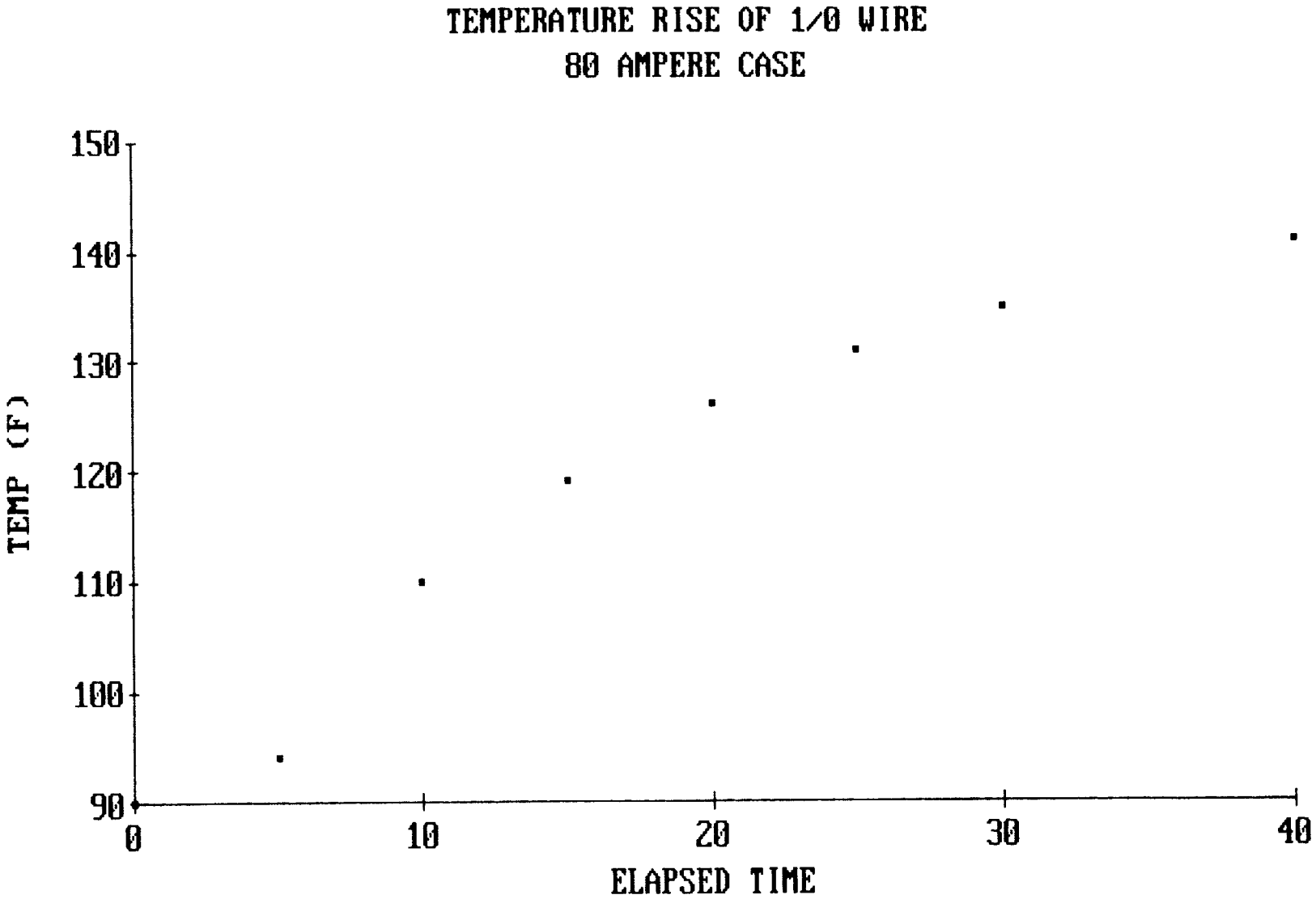
TEMPERATURE RISE OF 1/0 WIRE
80 AMPERE CASE
150
140
130
120
110
100
90
TEMP (F)
0
10
20
30
40
ELAPSED TIME

Figure 44

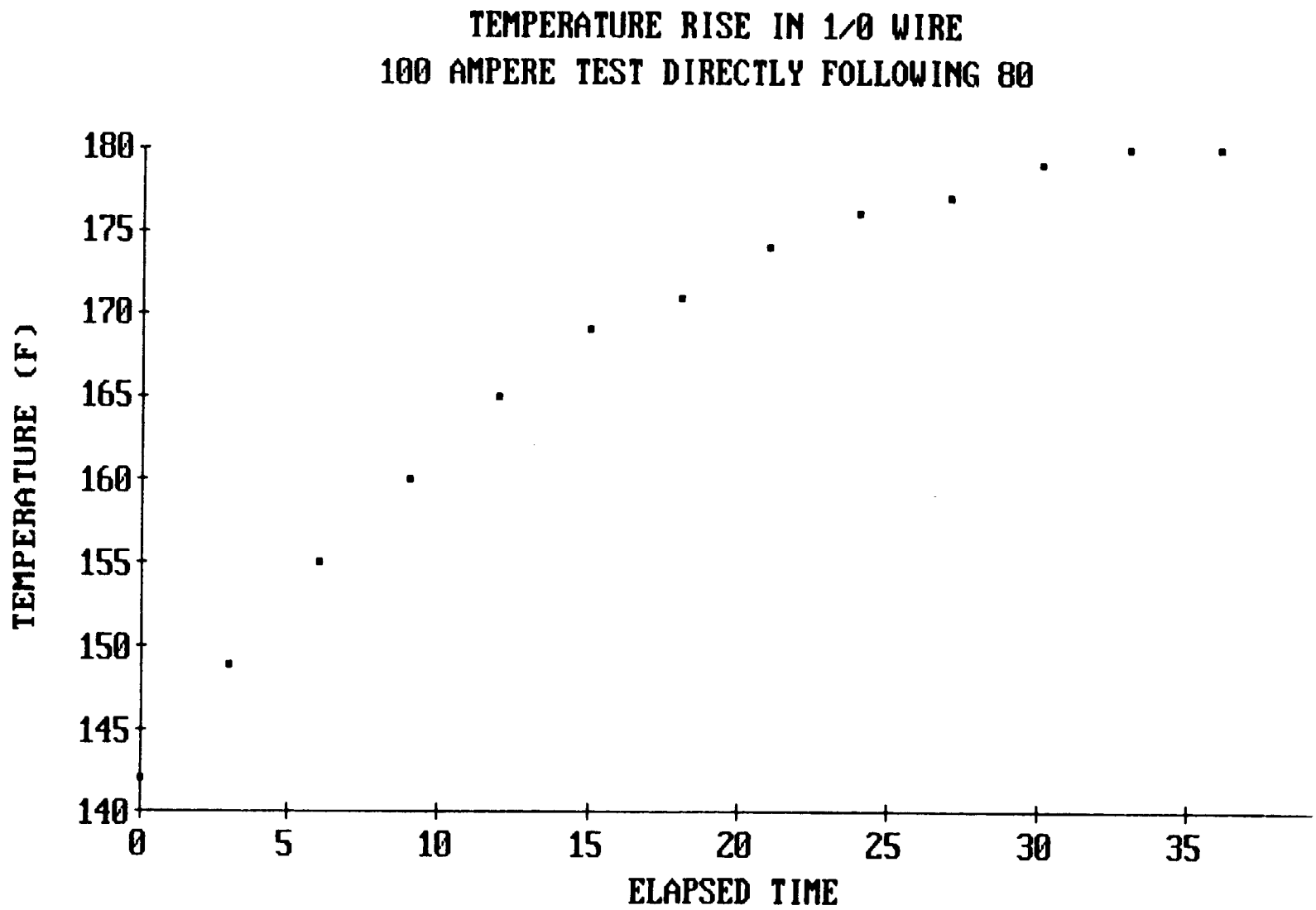
TEMPERATURE RISE IN 1/0 WIRE
100 AMPERE TEST DIRECTLY FOLLOWING 80
TEMPERATURE (F)
180
175
170
165
160
155
150
145
140
0
5
10
15
20
25
30
35
ELAPSED TIME

Figure 45